THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL.

VOL. 30. Thursday, September 11, 1924. No. 421.

PUBLISHED WEEKLY.

Subscription Terms: 15s. per annum.
Foreign and Colonial, 17s. 6d. per annum.
All Subscriptions are payable in advance.

All communications to be addressed to the Editor, or to the Publisher, as the case may be, of

THE FOUNDRY TRADE JOURNAL,
BESSEMER HOUSE, 5, DUKE STREET, ADELPHI,
LONDON, W.C.2.

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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN AND THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION.

Institute of British Foundrymen.

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Welsh Engineers' and Founders' Association.

Secretary: F. J. Griffiths, 20, Fisher Street, Swansea.

Special Libraries and Bureaux of Information.

During this last week-end an important conference has been held dealing with the various phases of the work, scope, and influence of the special library and bureau of information. Apparently a special library is a specialised organisation which collects data on defined subjects and renders them easily accessible to people interested. In this work they resemble the specialised Press, yet apparently rely on this source for a considerable proportion of their information. The object of the conference was to ascertain whether those interested in this work were prepared to form a definite or an indeterminate organisation so that a special library requiring data outside its normal scope could tap another bureau covering it, with the assurance that it would receive adequate attention. A committee has been formed to approach the Library Association, with the object, we presume, to achieve their *but* within that organisation. The special libraries realise their importance, because in a national crisis such as was presented during the war a reliable bibliography of military and naval and allied inventions became a necessity. There is some talk of a complete international bibliography of written knowledge being formed at Geneva under the League of Nations. Some dreamers attach such importance to this subject that they envisage a mobile system analogous to the Post Office, which would allow of foundrymen who required to know the influence of aluminium on cast iron to go to his local office and register his inquiry, and in a few days' time he would receive a number of cards giving a detailed international bibliography, or perhaps even abstracts of the subject. We believe that such a system, which, even if it could be evolved, would be disastrous to progress, because people would refrain from making public anything of an important nature, because they would have brought before them so vividly the accessibility of the information to foreign competitors. At the moment there are firms of world-wide reputation, who prefer that an invention should remain a trade secret rather than subject-matter for a patent application. In one such case an important American concern intimated that they could obtain a greater life by five years than that afforded by the granting of letters patent. We see but little need for the nationalisation, let alone internationalisation of specialised information. The special libraries and bureaux of information are usually privately subsidised and must remain private. The bulletins and little journals which they get out at great cost is their little way of making their supporters realise the work they are doing. As an aid to their principal object it is to be commended, but it sometimes assumes such importance and utilises such an amount of energy as to be top heavy.

The sphere of the special library and bureau of information should occupy a similar position to the technical adviser to a directorate—both are confidential. If the scope of information sought by an individual became known generally, the policy of a firm, association, or organisation might be jeopardised. After all, perhaps the best policy for special libraries to pursue is to remain in the background. If a bureau director can make an arrangement with other libraries, so much the better. If there are any foundries having an extensive library or bureau of information, they are invited to communicate with Mr. J. G. Pearce, the director of the British Cast Iron Research Association.

XUM

The Use of Pulverised Fuel in Malleable Foundries.

By C. H. S. Tupholme.

Where pulverised fuel is used in malleable foundries, hand firing is eliminated, and it is only necessary to have a furnace tender to regulate the coal and air supply at 15 or 30 minute intervals during the first two hours of each heat. It requires very few minutes of this man's time for the firing operation, the balance of his work being to keep the tapholes and bungs in proper shape, handle the skimming and cleaning up around the furnace. In most cases one man can take care of two furnaces, though it is very seldom possible to get a man to tend to more than one furnace.

In many malleable plants, in the afternoon the moulders get the floor full half an hour or an hour before the furnacemen can get the second heat ready to tap. On the other hand, when melting with pulverised fuel, the first heat may be run later in the morning and a large enough heat melted in the afternoon to pour off all the moulds. This gives a greater production per moulder and effects a marked saving in operating cost.

Using pulverised coal, malleable iron has been successfully melted with a fuel of less than 12,000 B.Th.U. and more than 16 per cent. ash, though it is questionable whether this is economical, as very much better fuel ratios are obtained when using coal that has 13,500 B.Th.U., or higher, and not over 8 per cent. ash.

Ordinarily, the slight difference between the cost of a fair-grade coal and a poor-grade will not warrant using the inferior variety, but screenings of a fair grade can usually be purchased at considerably less cost than lump or run of mine.

The saving resulting from less frequent brick renewals is no small factor in favour of pulverised fuel. In a hand-fired furnace an excess of air is required to maintain combustion, and the top blast is used to deflect flame on to the metal after it passes over the front bridge wall. This causes a cutting action on the side walls, and on nearly all furnaces the side walls are burned out very irregularly owing to the whirling action of the flame and the excess air during the time fuel is not being supplied to the furnace.

In some pulverised fuel-fired furnaces the flame is deflected downward and the top blast is omitted, as shown in Fig. 1. As a result the charge is heated on the bottom and when completely melted a circulating motion is created in the bath. This has a tendency to force the slag to the rear, leaving the metal near the burners free. This, in addition to the circulating motion, shortens up the heating period considerably.

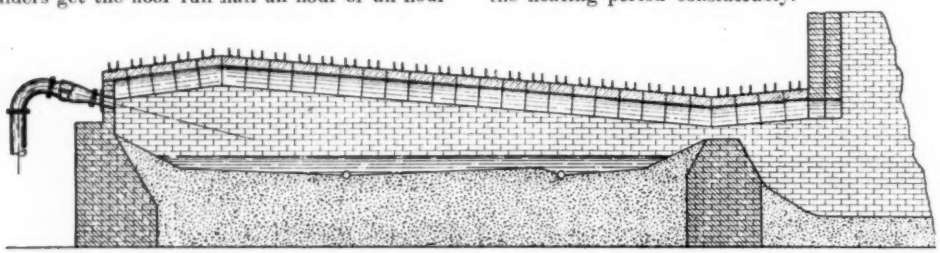

FIG. 1.—MALLEABLE IRON MELTING FURNACE DESIGNED TO UTILISE PULVERISED FUEL.

It has also been found that a cheaper grade of brick can be used with such a method of pulverised fuel firing, lasting longer than the higher grade brick does in the hand-fired furnace. Some furnaces after being equipped with pulverised fuel have been operated three times as long as was possible with hand-firing, and in most cases the furnace will last twice as long without repairing the side walls. On an average the bungs will last 40 per cent. longer.

On account of the good combustion obtained and the steady temperature, it is possible to use a greater percentage of scrap in the charge than with hand-firing. Some plants, which formerly used 53 per cent. pig-iron and no steel in the charge and endeavoured to maintain an average of 2.5 per cent. carbon, are now using 35 per cent. pig and maintaining an almost uniform carbon content of 2.5 per cent. Of course, when steel is used this amount of carbon cannot be secured unless more pig-iron is added, and about 1 per cent. additional pig-iron for each one per cent. of steel used in the charge is required.

Some furnaces fired with pulverised coal are being charged with 42 per cent. pig and 9 per

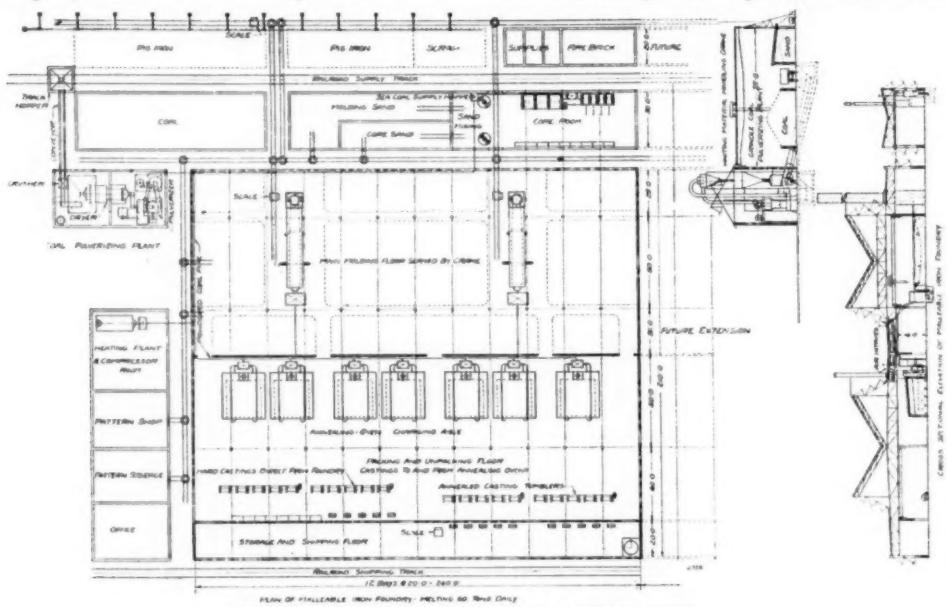

FIG. 2.—LAYOUT OF A MALLEABLE IRON FOUNDRY.

cent. steel, securing an average of 2.5 per cent. carbon. Since there is difference of opinion amongst foundrymen as to whether steel increases the tensile strength and elongation it is impossible to calculate any standard mixture, and in most cases it is better for the metallurgist to consult with the furnace designers. It has been found, however, that the monetary saving is sometimes greater when no steel is used, as the charge then requires less pig-iron, using malleable scrap instead.

Some engineers known to the writer who have installed pulverised fuel furnaces report 5 per cent. more good castings out of their melt. 2 per cent. of which they estimate is a reduction in scrap castings owing to the higher and more uniform temperature of the metal and fewer blow-holes in the castings. The balance of 3 per cent. represents more metal obtained from the charge owing to the decreased oxidation.

When applying pulverised fuel to a hand-fired furnace, the capacity should be increased by anything up to 40 per cent. By filling up the old firebox the bath is lengthened several feet, greatly increasing the size of the melting chamber. In many cases it is desirable to cut off a part of the old firebox using this space for installing the firing plant. This is especially true where the furnace is close to gangways, monorails or rail tracks.

Where pulverised fuel is used there is little waste in the form of unburned hydrocarbons. A small part of the incombustible material goes up the stack in the form of a very fine flocculent white powder, thoroughly calcined, and hardly visible at the top. The majority is removed with the slag and a small quantity of it settles at the base of the stack; this probably amounts to a few wheelbarrow loads per week.

When pulverised fuel was first applied to malleable furnaces, considerable difficulty was experienced in bringing the bath to the desired temperature without excessive oxidation losses and furnace repairs. This difficulty has been overcome where the burners enter directly into the hearth chamber, firing downward in such a manner as to cause the flame to heat the charge at the bottom first, and after the iron is completely melted to create a circulating motion to the bath so that all parts of the bath are quickly brought to a high temperature.

If pulverised fuel is installed for furnace firing, care must be taken to see that such a system is chosen where there is no possible chance of the fire flashing back into the burner pipes. Pulverised fuel is most dangerous when confined and suspended in large volumes of air moving very slowly, and in this way it is comparable to gas, though less likely to ignite. The whole system must be absolutely dust-tight, and hoppers should be vented to the outside air, except in special cases, where a dust-arresting system is used for collecting the small amount of dust from the air replaced by the coal in the hopper, and that used for conveying.

Institute of Metals.

The luncheon in connection with the annual autumn meeting was held at the Connaught Rooms, Kingsway, London, last Tuesday. The Chairman was Professor Thomas Turner, M.Sc., the President of the Institute. The toast of "The Institute of Metals" was proposed by Sir Westcott Abell, K.B.E. (President of the Institution of Marine Engineers), and responded to by the Chairman. "Our Guests" was proposed by Dr. John J. Haughton (Chairman London Local Section), and responses were given by Mr. H. M. Corse, B.S., of the International Nickel Corporation of America, and Mr. W. J. U. Woolcock, C.B.E. (President of the Society of Chemical Industry). About 275 members and friends took part. During the afternoon a visit was paid to the British Empire Exhibition at Wembley.

MR. JAMES HORNE has retired from active service with Vickers, Limited. Mr. Horne's special work has been the designing of heavy gun mountings and accessory mechanisms. He will continue to act in an advisory capacity to the firm.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

The Late Mr. Robert Buchanan.

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—It is with many sincere regrets that all associated with the foundry industries, especially members of the Institute of British Foundrymen, will learn of the passing away of Mr. Robert Buchanan.

To those who had the good fortune to know him personally, his loss will be very keenly felt, and it is because of this feeling that I desire to pay my sincere tribute to his memory.

All of us who were at any time associated with the late Mr. Buchanan cannot fail to have noted and admired his genial smile, openness of heart, and, above all, that rare and sterling characteristic of being so willing to give to others the benefit of a successful life's experience. It is, perhaps, some little consolation for his loss that he was spared to witness the splendid fruits of his most earnest efforts, as a founder of an institution which has gradually grown into one of the most important specialised institutions in the world.

I owe much to the kindness of the late Mr. Buchanan; it was due to the very sincere interest he so modestly displayed when I first became associated with him, that I attached myself to the foundry industries. Since that first meeting I have had the honour of spending many pleasant half-hours in his company; they were times of which I felt, and always shall feel, very proud, because Mr. Buchanan was to me a constant source of encouragement—"a man amongst men."—Yours, etc.,

H. H. SHEPHERD, M.I.Brit.F.

Chilled Castings.

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—Referring to the paragraph which appeared in a recent issue of your paper to the effect that Mr. P. H. Griffin, of New York, is at present visiting Europe and is desirous of extending operations in England, we are writing to inform you that we hold the sole right to manufacture and sell in Great Britain and the British Dominions, Dependencies and Colonies (Canada excepted) chilled wheels, chilled and grain rolls and other chilled castings according to the processes of Mr. Patrick Henry Griffin.

We should like to add that the parent Company is the Compagnie Europienne Griffin, of 2, Rue de Constantinople, Paris, and that, in addition to the French Griffin Works, there are Griffin Works operating in Belgium and Italy and other European countries.

We shall be much obliged if you will kindly give the same prominence to this letter as you did to the paragraph referred to.

Thanking you in anticipation—Yours, etc.,

For CHILLED CASTINGS, LIMITED,
H. C. MARRIOTT,
Managing Director.

27, Mincing Lane, London, E.C.3.
September 8.

International Foundry Trades Exhibition, Birmingham, 1926.

The Birmingham Chamber of Commerce has decided again to organise the International Foundry Trades Exhibition in 1926, upon the same lines as the previous two successful Exhibitions held in 1922 and 1924.

On inquiry, Mr. F. W. Bridges informs us that, under these circumstances, he has cancelled his arrangements for holding a Foundry Exhibition at the Agricultural Hall in 1926.

Institute of Metals Receives £1,000 Endowment

In the course of his opening address Professor Turner, the President of the Institute of Metals, announced a gift of £1,000 by Mr. L. Sumner, a past-president, which will aid the Institute to develop the library and other facilities which they give

Trade Talk.

OWING to the depression in trade, the rail mills at the Barrow Steel Works have been temporarily closed.

SIR W. G. ARMSTRONG, WHITWORTH & COMPANY, LIMITED, have secured an order for six locomotive boilers for the Buenos Aires Pacific Railway Company.

MR. S. R. MIDGLEY, of Midgley & Son, Limited, Sheffield, has been appointed North of England agent for Chalas & Sons, ore, metal and alloy agents and merchants, Finsbury Pavement House, Moorgate, London, E.C.2.

THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED, of Rugby, are extending their Willesden works, and have placed an order with the Cleveland Bridge and Engineering Company, Limited, Darlington, for a steel-framed building 450 ft. by 140 ft.

H.M. Senior Trade Commissioner in South Africa reports that a firm in Johannesburg are considering the question of installing a bolt and nut factory, and are desirous of receiving information from British manufacturers of suitable plant.

THE STROH STEEL HARDENING PROCESS COMPANY inform us that they are exhibiting their speciality at the Pittsburgh Exhibition, under the auspices of the Iron and Steel Electrical Engineers' Association, held at the Duquesne Gardens, from September 15 to 19.

THE CAPITAL of Sheffield Steel Products, Limited, is now £1,992,334 10s., divided into 522,999 unissued preference shares of £1 each, 727,001 issued preference shares of 10s. each, 1,019,300 unissued ordinary shares of £1 each, and 1,730,700 issued ordinary shares of 1s. each.

NAPIER & MILLER, LIMITED, Old Kilpatrick, have received from the Eastern Steamship Company, Limited, Port Colborne, Ontario, orders for two single screw steamers of 1,750 tons gross and 2,500 tons deadweight. Triple-expansion engines will be supplied by David Rowan & Company, Limited.

AS THE RESULT of operations in Scapa Flow during the week ended August 30, further progress was made in the task of salving the scuttled German Fleet, two destroyers being raised and towed on to the beach. Cox & Danks, Limited, employing the floating dock, raised their third vessel, and towed it into Mill Bay. The other destroyer was lifted by the Scapa Flow Salvage and Shipbuilding Company.

RICHARD JOHNSON, CLAPHAM & MORRIS, LIMITED, have removed to Jacem House, Trafford Park, Manchester. The company's offices and warehouse are now housed in the same building. The warehouse, with its 7,790 square feet of floor space, its modern equipment, its railway siding under cover in the building, from which goods are shipped and received, embodies the latest practice in handling hardware.

THE DIRECTORS of Bolckow, Vaughan & Company, Limited, have notified the holders of the 1,860,000 partly-paid ordinary shares of their intention to call up the balance of 8s. per share, making the shares £1 fully paid. This means an increase in the paid-up capital of £744,360, making the issued and fully-paid ordinary capital £5,024,960 out of £5,500,000 authorised.

THE REFRACTORY MATERIALS SECTION of the Ceramic Society will meet at the British Empire Exhibition on September 18 and 19, Mr. J. Holland presiding. The papers to be read include "A Comparison of Gas and Coke Fired Drying Stoves," by Mr. T. W. Barley; "Some Properties of Clay Sillimanite Mixtures," by Prof. J. W. Cobb and Mr. H. S. Houldsworth; and "The Action of Heat on Kaolinite and other Clays," by Dr. J. W. Mellor and Dr. A. Scott.

MR. W. L. HICHENS, chairman of Cammell, Laird & Company, Limited, declines to take a pessimistic view of the future of the steel industry. "It is clear," Mr. Hichens has stated to an interviewer, "if we are to hold our own in foreign markets, and this is essential to us, that our costs in the steel industry must come down still further. This can be achieved in a variety of ways, partly by improved mechanical methods, partly by a bigger output, and partly by improved organisation. It is possible, too, that wages may have to be still further reduced, since, in the long run, we cannot pay higher wages than our European rivals, and at the same time compete with them successfully in foreign markets, but this, in my view, is not an immediate necessity. There should as a first step be a correlation between the wages in the sheltered and unsheltered industries. I see no reason to believe that we cannot hold our own against German competition if we set our minds to it. The phrase 'trade war' I deprecate. We do not want to filch from the Germans the trade which lawfully belongs to them. We want rather to open up new markets and to tap new sources of consumers. There can be I am convinced, a place for the steel industries for Germany as well as for Great Britain and other countries."

Company News.

Central Provinces Manganese Ore.—Interim dividend, 10 per cent., free of tax.

Mansfield Engineering Company (1923), Limited.—Trading loss for two years, £3,803.

Thomas Gourley & Sons, Limited, 49, Rue-end Street, Greenock.—Capital £4,000 in £1 shares. Engineers, etc.

Scottish Tube Company, Limited.—Dividend on preference shares, 5 per cent. per annum, less tax, for half-year.

Chetwynd & Jones, Limited, 152A, Irving Street, Birmingham.—Capital £1,000 in £1 shares. Brassfounders, metal workers, etc.

Metropolitan Metalware Company, Limited, 97A, Aston Road North, Birmingham.—Capital £2,000 in £1 shares. Nut and bolt, etc., manufacturers.

Enfield Rolling Mills, Limited, Lincoln House, High Holborn, London, W.C.—Capital £50,000 in £1 shares. Coppersmiths, smelters, rolling-mill proprietors, etc.

R. H. Burman, Limited, Windmill Street, Birmingham.—Capital £5,000 in £1 shares. Engineers and founders. Directors: A. C. Allday and A. E. Millner.

Electricity (Scunthorpe), Limited.—Capital £1,000 in £1 shares. Electrical engineer. Directors: J. Wass, 53, High Street, Scunthorpe; E. Taylor and F. N. Slater.

R. McPhail & Stewart, Limited, 98, West Regent Street, Glasgow.—Capital £3,000 in £1 shares. Engineers and founders, etc. Directors: R. McPhail and H. J. Stewart.

Ferranti, Limited.—Net profit, £55,545; brought forward, £25,164; available, £71,188; reserve, £35,000; dividend, 15 per cent., free of tax, on ordinary shares; carried forward, £27,188.

David Smith (Govan), Limited.—Capital £10,000 in £1 shares. Iron and steel merchants, etc. Directors: D. Smith and R. Smith. Solicitors: David Harper & Watson, 65, Bath Street, Glasgow.

R. Wilson & Sons, Limited, The Forge, South Church Lane, Bishop Auckland.—Capital £30,000 in £1 shares. Engineers, etc. Directors: R. Wilson, M. S. Hall, T. Wilson and T. Wilson, Junr.

Gough's General Distributing Company, Limited.—Capital £25,000 in £1 shares (24,900 ordinary and 100 founders'). Coal, iron and steel merchants and agents, etc. Directors: H. G. Gough and P. E. Rush, "Penrith," Welbeck Avenue, Southampton.

Pyros Chemical & Engineering Company, Limited, 59, New Bridge Street, London, E.C.—Capital £2,000 in 1,500 10 per cent. cumulative preference shares of £1 and 10,000 ordinary shares of 1s. Directors: A. B. Falkner, H. P. Hansen, F. M. Haman and S. W. Kendal.

Wright, Bindley and Gell, Limited.—Balance, including amount brought in, £16,641; interim preference dividend, £2,502; final dividend on preference shares, £2,502; dividend, 5 per cent. for year on ordinary shares, free of tax, £6,562; reserve fund, £2,000; carry forward, £3,075.

Wm. Jas. Glover & Company, Limited, 83, Liverpool Road, St. Helens, Lancs.—Capital £35,050 in 10,000 7½ per cent. 1st cumulative preference, 15,000 7½ per cent. 2nd non-cumulative preference, and 10,000 ordinary (5,000 A and 5,000 B) shares of £1 and 1,000 deferred ordinary shares of 1s. Wire rope and cable manufacturers, etc. Directors: H. P. Glover and K. B. Glover.

Compagnie des Minerais de Fer Magnetique de Mokta-el-Hadid.—This concern reports for 1923 an output of iron ore of 381,531 tons (an increase of about 100,000 tons on 1922) and shipments totalling 521,440 tons (an increase of over 60,000 tons on 1922). The excess of shipments over output was made up from stocks.

EXPORTS OF IRON ORE from Melilla during the first seven months of 1924 amounted to 258,915 tons.

THE PRIME MINISTER has been in communication with representatives of the chief British industries, and is setting up a committee to advise the Foreign Office with regard to the effects of European economic changes and of European combinations against British trade.

COMPRESSIVE STRENGTH OF IRON ORE.—Recently 125 compression tests have been made by the U.S. Bureau of Standards on specimens of iron ore from the Birmingham (Alabama) district. A portion of these tests was made in the usual manner while in others the specimens were subjected to vibration during the test. The strengths obtained varied from 10,000 to 17,000 lbs. per sq. in. No appreciable reduction in strength was observed because of the vibrations.

Comparative Tensile Properties of Aluminium Alloys as Obtained on Separately-Cast Specimens, and Specimens Cut from a Crank-Case Casting.*

By E. H. Dix, Jun., M.E., M.M.E., and First-Lieut. A. J. Lyon, B.S. (Dayton, O., U.S.A.).

Introduction.

It is a well-known fact that separately cast test-bar results furnish insufficient information in themselves upon which to judge the relative casting qualities of aluminium casting alloys. Many alloys show good physical properties when cast in the simple shape of a test-bar, but fall far short of these properties when cast in a complex shape, due to internal stresses and porous or spongy metal. Too often the designer does not consider the casting qualities of an alloy, and bases his choice merely on the physical properties obtained in separately cast test-bars, generally specification values. This is probably due to the lack of reliable data on the comparative physical properties to be expected in large castings. It was to furnish such information to aircraft designers that the following investigation was undertaken by the Metallurgical Section, Engineering Division of the United States Air Service.

Melting.

For the manufacture of the alloys used in melts 1487 and 1609, the copper and silicon were introduced by the use of copper- and silicon-rich hardeners. The chemical composition of these and the aluminium ingot used are given in Table II:—

TABLE II.—*Metal Chemical Composition.*

	Copper	Iron	Silicon.	Aluminium.
Copper-aluminium hardener ..	46.21	0.42	0.22	53.15
Silicon-aluminium hardener ..	0.30	1.23	50.68	47.79
Ingot aluminium ..	0.30	0.58	0.94	98.18

The procedure for the manufacture of the copper-silicon and the 8 per cent. copper-aluminium alloy was to charge the required amounts of hardeners and aluminium ingot together in a No. 125 plumbago crucible and melt in a gas-fired crucible furnace. Temperatures were measured with a Chromel-Alumel thermocouple and Leeds & Northrup potentiometer. Test-specimens cast to size in greensand moulds, as described above were poured from each of these melts and the balance pigged. The crank-cases, which were moulded in greensand, were then poured from the remelted ingots and additional test-specimens poured just before the castings. The pouring temperature was 774 deg. C. in both cases.

The details other than method of gating and of placing the risers pertaining to the melting practice of the other two alloys, namely, melts 1780 and 2702, are not known. The Lynite 195 crank-case was heat-treated subsequent to casting by the manufacturer, and the details are not available.

TABLE I.—*Composition of Alloys Used.*

Foundry Melt No.	Alloy.	Copper.	Iron.	Total silicon.	Combined silicon.	Graphite Silicon.	Manganese.	Magnesium.
1487	A.S.A.I No. 5 (Exp.) ..	3.47	1.25	4.10	—	—	—	—
1609	No. 12	8.06	0.74	0.78	—	—	—	—
1780	Alpax metal	0.02	1.15	12.72	4.86	7.86	—	—
2702	Lynite 195	4.57	0.55	0.45	—	—	0.11	0.10

Foundry Practice.

The upper half of the Liberty 8 crank-case was selected as a representative casting, embodying thick and thin sections. Its approximate weight with risers attached was 100 lb. when cast in an 8 per cent. copper-aluminium alloy.

The chemical analyses of the alloys from which the castings were made are given in Table I. The melt number will be used for purposes of identification throughout this Paper.

Alloys of melts Nos. 1487 and 1609 were mixed and the castings made by McCook Field Foundry,

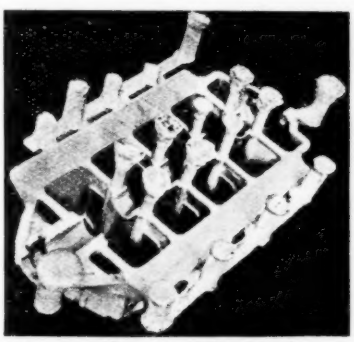

FIG. 1.—METHOD OF GATING CRANK-CASES. MELT NO. 1,487.

and the other two by commercial aluminium foundries.

The methods of gating and of placing the risers on the four castings are shown in Figs. 1 to 4. Separately cast test-specimens ½ in. dia. over a gauge length of 2 in. were cast three in a mould, the individual specimens being fed by a common riser 1¼ in. dia. and 3 in. in height at one end, and a pouring sprue of the same dimensions at the other. Test-specimens in the form of coupons were also cast from melts 1780 and 2702, as shown in Fig. 3.

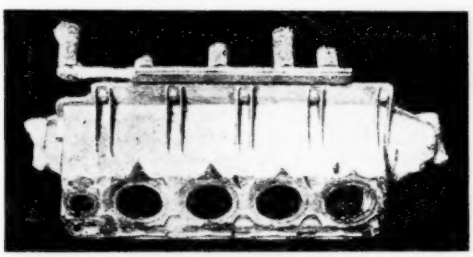

FIG. 2.—METHOD OF GATING CRANK-CASES. MELT NO. 1,609.

Comparison of Casting Characteristics of Different Alloys.

No. 12 (8 per cent. copper, 92 per cent. aluminium) is a standard casting alloy which has been used almost exclusively in America for crank-cases, pump bodies, cover plates, and other miscellaneous castings in aircraft engines. The alloy has a very wide commercial use. It, in common with most aluminium alloys, has a tendency to form shrinkage cracks and draws, and the U.S. Air Service has experienced difficulty with this

* Extract from a Paper presented to the Autumn Meeting of the Institute of Metals. The authors are connected with the Engineering Division, United States Air Service.

alloy cast in the form of large crank-cases. The difficulty was overcome, but at the cost of increasing the weight of the casting and a high foundry loss from poor castings. The crank-case, however, cast in connection with this investigation, gave no trouble in the foundry, in spite of the fact that no chills were used.

The copper-silicon-aluminium alloy has the advantage over the No. 12 alloy in being free from excessive draws, cracks, and other similar foundry defects. Its greatest use has been found as a substitute for No. 12 alloy in designs where the latter alloy gives trouble in the foundry. It is particularly well adapted for castings which are designed for the most economical weight and which have heavy and light sections adjoining. Large castings can be poured as thin as $\frac{1}{4}$ in. satisfactorily.

Lynite 195, an aluminium-copper-magnesium alloy, is a commercial alloy in the United States, with the source of supply limited to one producer. This alloy must be heat-treated in order to develop its maximum physical properties, so with the present commercial methods of heat-treating special provisions for the use of this alloy must be made in designing in order to prevent excessive initial stresses, cracks, and warpage from being developed in heat-treating operations. Referring to Fig. 4, it can be seen that the methods of casting this alloy are more complicated than any of the other three alloys under investigation, and the casting made in this manner showed quenching

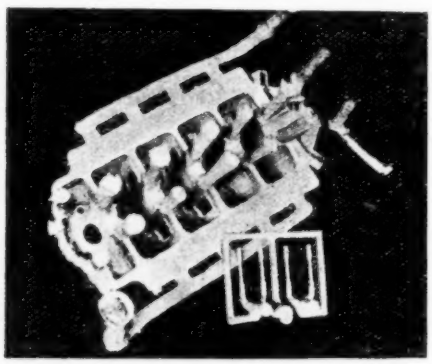

FIG. 3.—METHOD OF GATING CRANK-CASES. MELT NO. 1,780.

cracks where the webs join walls of the crank-case, so that it would have been unfit for use. This could have been prevented by slight changes in design, but was not thought worth while for the purposes of this test. The greatest application for Lynite 195 is in castings of practically uniform section, where a saving in weight can be effected by using an alloy with superior physical properties.

Alpax, which is a modified 13 per cent. silicon alloy of aluminium, has practically the same casting properties as the copper-silicon-aluminium alloy. Experience has shown that this alloy gives some trouble in the foundry, due to the presence of cavities in the form of worm holes in the heavy sections. It has a limited source of supply, and special manipulation is required for the modifying process.

Selection of Tensile Specimens.

Fifty-six proportional test-specimens were cut from each of the crank-cases. These were arranged according to their location in eight series and are shown in Fig. 5, and are described in the following tabulation:—

Series A.—Eight specimens 0.505 in. diameter were cut from the bearing support bosses, which are of oval section, the dimensions of which are approximately 1 × 1½ in. Two modulus specimens, $\frac{3}{4}$ in. in diameter and 8 in. gauge length, were cut from the centre bearing support bosses.

Series B.—Sixteen specimens $\frac{3}{8}$ in. in diameter were cut from $\frac{3}{8}$ in. flange; the gauge diameter of the specimen practically including the full thickness of the metal.

Series C.—Six specimens $\frac{3}{4}$ in. in diameter, standard threaded ends, were cut from the bottom of the web to the two end members. Odd numbers right hand, even numbers left hand (facing propeller).

Series D.—Six specimens $\frac{3}{4}$ in. in diameter, standard threaded ends, were cut from between the cylinder flanges. The metal here has a thickness of $\frac{3}{4}$ in. Odd numbers right hand, even numbers left hand.

Series E.—One specimen from the boss between A1 and A2, 0.505 in. standard threaded end. The diameter of this boss is $\frac{3}{4}$ in.

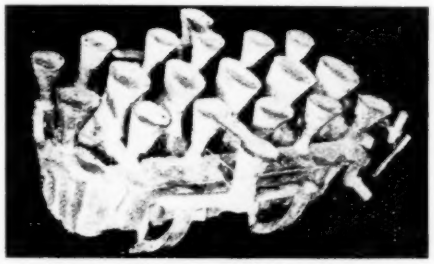

FIG. 4.—METHOD OF GATING CRANK-CASES. MELT NO. 2,702.

Series F.—Eight specimens were taken from the outside walls of the case. This series consist of a flat pin-ended specimen, having the full wall thickness of $\frac{1}{4}$ in. The specimens taken from the walls of the copper 8, aluminium 92, crank-case were first made $\frac{3}{4}$ in. wide. The enlarged ends were made 1½ in. wide by 2 in. long, and a $\frac{1}{2}$ in. hole was drilled for pulling in pin-ended adapters in order to secure axial loading. It was found that most of the fractures occurred in the enlarged end of the specimen, so for this reason the specimens from the other three crank-cases were made $\frac{1}{2}$ in. wide over the gauge length and 2 in. wide in ends, with a $\frac{1}{2}$ in. diameter hole for the pin. These were also made full thickness of the metal. The casting skin was not removed. These dimensions proved very satisfactory, and most of the fractures occurred in the middle of the gauge length (2 in.).

Series G.—Three flat pin-ended specimens were taken from the fin web between the bearing support bosses; the web at this point is $\frac{1}{4}$ in. thick. The dimensions of the specimens were the same as series F, and the same trouble was experienced with those cut from the 8 per cent. copper-aluminium crank-case, and the dimensions changed as described above.

Series H.—Six specimens were taken from the bosses at opposite ends of the case; these were standard proportional specimens $\frac{3}{4}$ in. diameter with threaded ends. The thickness or diameter of the bosses is $\frac{3}{4}$ in. The gauge length of the U.S. Air Service standard proportional dimensions is four times the diameter.

Physical Testing.

The standard round threaded end specimens of Series A, B, C, D, E, and H were tested in self-

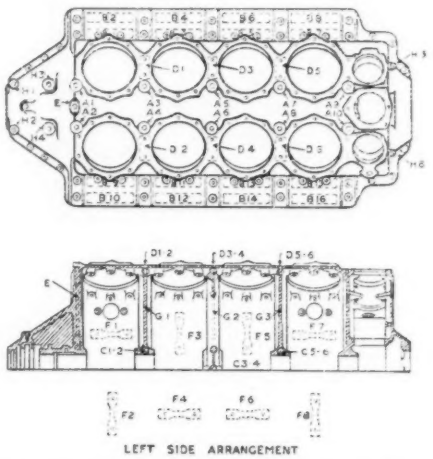

FIG. 5.—POSITION OF TEST SPECIMENS IN CRANK-CASE.

aligning adapters in a 20,000-lb. Olsen universal machine, using a 10,000-lb. poise. The specimens of Series F and G were tested in pin-ended adapters

in the same machine. The separately cast tensile specimens, including those attached as coupons to the crank-cases, were tested, without machining, in wedge grips. The modulus of elasticity specimens, Series A, were tested in self-aligning adapters, and the loads applied in increments of 200 lb. Deflections were measured by means of a Ewing extensometer. These results were plotted to a large scale and reduced.

results of the modulus tests, however, showed that the order of proportional limits (see Fig. 6) is somewhat different. The 8 per cent. copper-aluminium alloy is next to Lynite 195, followed by the copper-silicon-aluminium and the Alpax. Alpax in particular has a very low proportional limit, and since this property is a criterion on which the usefulness of the different alloys are determined for U.S. Air Service use, it is apparent

TABLE III.—*Summary of Results on Specimens from Crank-Cases.*

Location.	Series.	Melt No. 1609.		Melt No. 1487.		Melt No. 1780.		Melt No. 2702.	
		Ultimate stress Tons per sq. in.	Elongation per cent. on 2 in.	Ultimate stress Tons per sq. in.	Elongation per cent. on 2 in.	Ultimate stress Tons per sq. in.	Elongation per cent. on 2 in.	Ultimate stress Tons per sq. in.	Elongation per cent. on 2 in.
Bearing support bosses	Average A 1 to A 4 and A 7 to A 10	6.04	Less than 0.5	7.02	0.81	9.40	4.3	10.90	2.9
Centre bearing support boss	Average A 5—A 6	5.74	0.25	6.59	0.63	8.78	4.0	10.58	1.68*
Flange: Right hand, 1–8 Left hand, 9–16	Average B 1 to B 16	7.69	—	8.16	1.5	8.13	2.9	11.13	3.0
Bottom web to 3 centre bearings	Average C 1 to C 6	8.20	—	9.24	1.5	10.30	4.9	10.81	2.4
Between cylinder flanges	Average D 1 to D 6	5.63	—	6.55	1.5	9.56	5.1	10.20	2.8
Boss between A 1 & A 2	E-1	—	—	6.812	1.00	8.77	4.5	11.77	3.5
Outside walls of case..	Average F 1 to F 8	6.34	—	9.13	1.8	7.49	2.6	10.44	1.8
Thin web between bearing bosses ..	Average G 1 to G 3	4.38	—	10.05	1.5	9.05	3.3	9.90	1.7
From bosses at opposite ends of case. 1–4 from propellor end	Average H 1 to H 6	5.24	—	7.61	1.1	10.37	5.0	10.99	3.8
† Grand average ..		6.62	—	7.97	1.4	8.89	3.7	11.00	2.4

* Modulus specimens, elongation on 8 in.
† Series F and G omitted because of difficulty due to dimensions of specimens.

Brinell, scleroscope, and Rockwell hardness tests were made on the transverse sections from the ends of the separately cast test-specimens. For Brinell test a load of 500 kg. with a 10-mm. ball was used; also scleroscope readings were taken with the magnifying hammer.

Specific gravity determinations were made on the same specimens that were used for the hardness determinations. The results of these tests are shown in Tables III and IV.

that Alpax is unsatisfactory, since it is impossible to take advantage of the relatively high strength and ductility on account of the ease with which it deforms under load.

In connection with the foundry technical control, it has been observed that, in the alloys of straight copper-aluminium type, the removal of the surface skin from the separately cast test-specimen results in a reduction of the ultimate or breaking strength of 20 to 25 per cent., while the

TABLE IV.—*Results of Tests on Separately Cast and Coupon Specimens.*

	3 per cent. Copper.	4 per cent. Silicon.	8 per cent. Copper.		Alpax Metal.		Lynite 195.
Melt No.	1486	1487	1608	1069	1780	1780	2702
Tensile stress (tons per sq. in.) ..	8.749	8.392	8.709	7.996	11.450	10.848*	14.213*
Elongation (per cent. in 2 in.) ..	1.5	2.0	2.0	1.5	7.25	3.5	5.25*
Brinell hardness (500 kg. load, 10-mm. ball)	50.00	48.00	52.5	52.00	55.00	—	68.00
Scleroscope hardness	12.00	12.00	17.00	18.00	20.00	—	22.00
Specific gravity	2.724	2.703	2.825	2.78	2.826	—	2.777

* Results from specimens attached to Lynite and Alpax crank-cases.

Comparison of Physical Results for Different Alloys.

From an inspection of Tables III and IV it may be seen that the average ultimate strength of the different alloys, as determined from the proportional specimens, are in the same order as those obtained from the separately cast tensile specimens, namely, Lynite 195, Alpax, copper-silicon-aluminium, and 8 per cent. copper-aluminium. The

effect of removing the skin or machining the specimens from the copper-silicon-aluminium alloy results in practically no reduction in strength. The results of the tests of the proportional specimens taken from the crank-cases show practically the same relation to the separately cast specimens —namely, Lynite 195 shows reduction of 24 per cent., and the No. 12 alloy and Alpax 21 per cent., while copper-silicon alloy shows only a reduction of

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4 per cent. This accounts in part for the difference between the separately cast test-specimens tested with the skin on and the machined specimens from the casting.

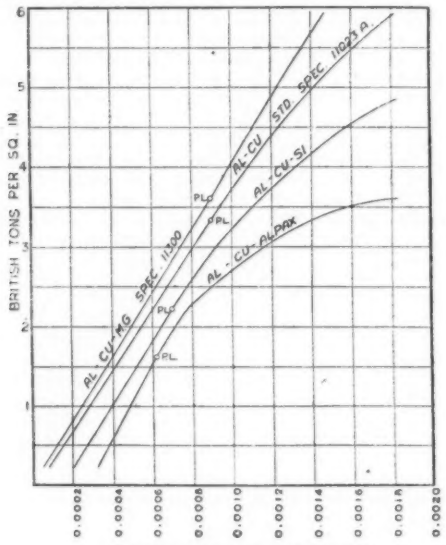

FIG. 6.—STRESS-STRAIN CURVES. COMPARISON OF CRANK-CASE ALLOYS.
SPECIMENS FROM CENTRE-BEARING SUPPORT.

Analysing the physical results obtained on the specimens taken from different parts of the crank-case, it may be seen that Lynite 195 gives the most uniform values throughout. This would be expected, since the crank-case was heat-treated subsequent to casting. Specimens taken from outside walls of the crank-case (Series F) and from the thin web between the bearing bosses (Series G) showed the most consistent and highest results for copper-silicon-aluminium alloy, while the results of the other three alloys are not as consistent, and are below the average values. The specimens taken from the bearing support bosses (Series A) show results which are below average for all of the alloys, and in case of the copper-silicon, 8 per cent. copper and Alpax, the metallographic examination showed that those sections were not sound, due to the relatively greater mass and slower cooling. The slow rate of solidification is probably responsible for the low properties.

Summary.

Table V gives a summary of the comparative physical results obtained on separately cast tensile specimens and on the proportional specimens cut from the crank-cases.

TABLE III.

Alloy.	B. Test pieces from Crank-cases.			A. Separately cast Test-pieces.	
	Limit of proportionality. Tons per Sq. in.	Maximum stress Tons per Sq. in.	Elongation on 2 in. per cent.	Maximum stress Tons per Sq. in.	Maximum stress B. / Maximum stress A.
No. 12	3.42	6.62	—	7.99	0.82
Cu-Si	2.39	7.97	1.4	8.39	0.95
Lynite 195 ..	3.68	11.00	2.4	14.21	0.77
Alpax	1.65	8.89	3.7	11.15	0.79

From the results of the investigation summarised herein, it has been concluded that the copper-silicon-aluminium alloy is particularly well adapted for complicated castings which do not require a large amount of machining. In many parts used in the construction of aircraft engines, such as crank-cases, manifold, cover plates, and housing, very little machining is required, and the finishing of the castings can practically all be done on a milling machine. This copper-silicon alloy is particularly well adapted for this type of work, and is recommended as a substitute for the No. 12 alloy wherever foundry difficulties due to shrinks, draws, and cracks offer serious trouble. The casting properties of Alpax are very similar to those of the copper-silicon-aluminium alloy, but it is not considered a practical alloy from the Air Service standpoint, due to the fact that it has a very low proportional limit and is inferior to the copper-silicon alloy in this respect. Lynite 195 is shown to have uniform and desirable physical properties. The proportional limit is considerably above any of the alloys tested. The foundry practice, however, is more difficult for this type of an alloy, and the fact that it has to be heat-treated increases the cost of production. The tendency to warp and crack during the heat-treatment would necessitate provision being made in the design for the use of this alloy; that is, a large complicated casting designed for either No. 12 or copper-silicon-aluminium alloy probably could not be poured in Lynite 195 with any degree of success. Eight per cent. copper-aluminium alloy is suitable for the general run of castings and can be cast in sections 3/16-in., or greater, in thickness without any great trouble. It is liable to shrinkage cracks, but this can largely be overcome in many designs.

The Extrusion of Brass Rod by the Inverted Process.*

BY R. GENDERS, M.B.E., B.MET.

The experiments described in this Paper and carried out on a manufacturing scale, although not sufficiently extensive to constitute a complete study of the method of extrusion of brass rod by the inverted process, have provided ample data to show that the inverted process is incapable of producing internally defective rod when sound billets are used.

Precautions are necessary to secure good surface, the method adopted for the present being the avoidance of entrance of the skin of the billet into the region of flow. The increase in the proportion of discard so produced, although rendering the ejection of the billet shell more simple, brings the total discard above the ideal minimum of about 5 per cent., which might otherwise have been possible. Even so, however, the proportion is considerably less than in the ordinary method.

The observations of the relative pressures required by the two processes operated on a small scale are fully confirmed by the large-scale practice. For the same types of material the pressure required by the new process is about 25 to 35 per cent. lower than for the ordinary process.

The structure of the extruded rod does not show the concentric zones of material varying in crystal size and physical properties often produced by the peculiar nature of the flow which obtains in the ordinary process. The rear portion of the rod is variable in structure and hardness from centre to outside, but in a continuous gradient.

For the manufacture of ornamental sections and other types of material in which absolute reliability is not essential or is subordinate to the requirement of immaculate surface, the advantage of the inverted method lies mainly in its saving power. For certain purposes it may be limited to some extent by the dimensions of the hollow plunger, although it is estimated that with a 1,000-ton press a container of 8¼-in. dia. and a plunger of 5½-in. bore can be used.

For the production of engineering material, however, the inverted method possesses the advantage that all possibility of the occurrence of the "core" defect is excluded, and that, if defects are allowed to arise, they will be visible on the surface of the rod. It is thus safe to extrude the billet nearly completely and so reduce scrap to a minimum without risk of the rod being affected internally.

The experiments carried out have been confined to the production of 1-in. rod, but no serious difficulty is foreseen in the application of the method to the varied practice of the modern works.

* Summary of a Paper presented at the Annual Autumn Meeting of the Institute of Metals.

The Analysis of Grey Iron Foundry Alloys.—IV.

By H. H. S.

The Estimation of Sulphur.

The estimation of this element in respect of cast iron has always been the subject of much controversy and concern to the metallurgical analyst, not so much in the direction of obtaining accurate results—with the application of care and common sense the barium sulphate or gravimetric method gives results of unquestionable accuracy—as in the founding of a method by which the estimation could be made sufficiently rapidly to meet the daily scientific control requirements of a modern foundry, and yet maintain the degree of accuracy necessary to ensure proper and adequate control of works practice. As pointed out above, the problem of accuracy was solved by the introduction of the barium-sulphate method, but this process is far too slow for daily routine requirements, not only is the time taken, from the commencement of the determination to the arrival at the result, considerable, but also that during which the analyst's attention is required. The problem of rapidity has been solved by the introduction of the volumetric process, the general principle of which is the action of an acid on the metal releasing the sulphur in the form of the gas sulphuretted hydrogen (H_2S). The gas is passed into a solution of a metallic salt, with which it reacts to give a soluble or insoluble sulphide, this sulphide is subjected to acid attack in the presence of iodine, H_2S is again released and immediately reacts with the iodine to form hydriodic acid (HI) and free sulphur. From the amount of iodine required the quantity of sulphur can be estimated.

The above remarks apply to practically all the methods of the volumetric or more correctly the evolution type, adapted to the determination of sulphur. It is not proposed to deal with the many modifications of the method, suffice it to state where a soluble sulphide is aimed at sodium or potassium hydroxide is the absorbent used: where an insoluble sulphide is preferred, zinc or cadmium, chloride, sulphate or acetate is used, if the chloride or sulphate, the solution is usually an ammonical one, while that of the acetate a dilute acetic-acid solution.

Of the absorbents mentioned, the ammonical solution of cadmium chloride is recommended as being the most satisfactory, the alkali absorbents are, in the writer's opinion, somewhat messy and inconvenient to handle, and in the hands of the junior often give unreliable results. The cadmium salt is clean to handle and gives an easily discernible precipitate of its sulphide, this factor alone is of much advantage to the operator, since to some extent he can form an idea of the quantity of sulphur present, and so often eliminate any doubt.

The Evolution Method.

There are several important points to note in connection with this method of estimation. It is often stated that this method is purely a comparative one, hence the necessity for employing, in the case of cast iron, a *cast iron* standard containing a known amount of sulphur estimated by the *absolute* method, *i.e.*, the $BaSO_4$ method. While this is correct so far, the explanation of the term "comparative" is often misleading, this is the case when it is stated that it matters not whether all or only part of the sulphur is evolved, so long as the samples are treated in the same manner, because the iodine equivalent of a certain amount or percentage of sulphur is known, upon dividing the c.cs. into the sulphur per cent. Again, it is usually stated in text books that the standard must be of the same class of material, and have undergone the same treatment in manufacture or works practice as the samples under test: while this is to a large extent an admitted truth, woe betide the analyst; especially if he has only a small staff, and is associated with a foundry employing many differing makes, brands and numbers of pig-iron in several differing mixtures; if he attempts to adhere religiously to this statement of an ideal and tries to carry it into practice to any great extent.

The essential basis for obtaining accurate results by the evolution method, is that *the standard must, upon suitable treatment, yield the whole of its sulphur as H_2S gas*; in the writer's mind this important factor is far too often ignored or not appreciated as to its influence.

Simple as the explanation of why this is so necessary may seem, it rarely finds its way into textbook descriptions, yet it is the most important factor of the method. It is not always juniors who are ignorant of this, the writer has in mind a case where two firms, a consumer and a supplier of pig-iron, contested over the sulphur content of a consignment of pig-iron, the former saying that the amount was much above normal, the latter that it was not. In both cases the sulphur was determined by evolution, and the repeated checks upon his results by the consumer agreed so close as to make him assured of their correctness, the variation of his figures from those of the supplier was too large to be accounted for by the often accepted statement that the method usually gives slightly higher results than the correct.

On submission of the sample to the $BaSO_4$ method the supplier was proved to be correct, and it was found that the standard, which had only recently come into use, did not yield all its sulphur under the evolution method, while the pig-iron in question did, hence the estimations were not comparative, the standard gave a high factor, causing the sample to give a high result.

To ascertain if the standard cast iron gives up all its sulphur as H_2S, it is necessary to prepare the iodine solution a little more carefully than is often usual. Resublimed iodine of the purest grade should be used, and the weight taken for the standard solution should be accurate to three decimal places. If these points are adhered to and care is taken to avoid loss of iodine on making the solution, it is unnecessary to standardise it against a solution of thio-sulphate, in fact, the writer's experience is that it is unwise, for the pure resublimed iodine is invariably much purer than thio-sulphate.

The iodine solution must, of course, be made up to a definite fraction of "normal" strength so that its sulphur value per c.c. can be estimated; with this information at hand one can easily ascertain the actual amount of sulphur given off by the standard. The iodine will not vary to any appreciable extent over a period of two months or more if kept in a dark blue or brown bottle having a well-fitted glass stopper. If towards the end of the volume of solution, it should indicate a changed sulphur value as calculated from the theoretical sulphur equivalent; the correct factor is found by dividing the number of c.cs. of iodine used into the percentage of sulphur the standard is known to contain. This is, of course, only permissible for a standard already in use, and proved to yield all its sulphur. The factor calculated in this way should agree closely with that calculated from the theoretical sulphur value of each c.c. of iodine.

The second point of importance in connection with the evolution method is the size of the particles of the sample drillings, though this is dealt with in the first article of the series, the effect of the condition or size of the particles is of such import as to warrant repeating, that they should be fairly uniform, *i.e.*, free from large drillings obtained by sieving the particles passing a 30 sieve being used.

The third point, which is sometimes of even greater importance than the preceding two, concerns the acid used, HCl is recommended, and the strength given is recognised as being the most convenient and satisfactory. The essential in this case is purity of the acid, particularly in respect of *freedom from free chlorine*.

The presence of free chlorine in any quantity is usually quite easily detected by the naked eye; the acid being yellow instead of colourless, the

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more intense the colour the greater the percentage of free chlorine presence. A more accurate test can be made by diluting 5cc. of the acid with an equal volume of distilled water, to this add 5 cc. of a 1.0 per cent. starch solution, and a few drops of 5.0 per cent. potassium iodide (K1). The presence of free chlorine is immediately indicated by the solution assuming a blue tint.

The effect of free chlorine is to reduce the number of ccs. of iodine required by a sample since free iodine is released from the potassium iodide contained in the iodine solution; should the standard have been treated with acid containing free chlorine, the same type of error will be introduced as is referred to previously in regard to irons which do not evolve all their sulphur, and one must be careful that the cause is not put down to the peculiarity of the iron when it may in fact be due to the acid used.

Before giving the results of a series of experiments and estimations made to ascertain the effect of the purity of the acid, it is advisable to point out that the supplies may in no way be at fault in respect of the acid they supply, as long storage in the laboratory, especially if exposed to sunlight, will cause the formation of free chlorine. On receiving a consignment of hydrochloric acid it should be examined and any bottles showing distinct yellow colouration either returned to the supplier, or kept for purposes other than sulphur estimations; a good plan is to pick out the bottles of colourless acid and store them in a cupboard away from the light.

In the series of experiments referred to above two pig-irons standards were used containing 0.078 and 0.103 per cent. of sulphur. They were treated in series by the evolution method, using dilute HCL made from winchesters of HCL containing varying amounts of free chlorine, while one series was made using acid containing no free chlorine. The following figures show the average of the results obtained :—

No.	Acid colour.	% S in std.	C.c. iodine required	% factor.
1	Colourless ..	0.078	11.7	0.00666
2	Distinctly yellow	0.078	11.2	0.00696
3	Deeper yellow ..	0.078	9.9	0.00787
4	Colourless ..	0.103	15.7	0.00656
5	Yellow	0.103	14.0	0.00736

The "per cent. factors" given above were obtained by dividing the number of c.cs. of iodine into the percentage sulphur content of the respective standards.

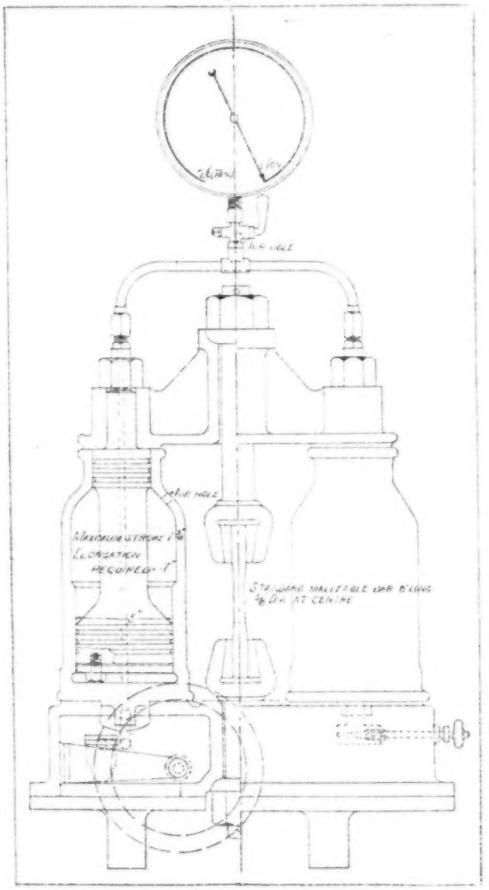
This point respecting the presence of free chlorine is made even more plain if the above factors are applied to illustrate examples.

Assuming that a standard is determined for its factor by the value of $\frac{\text{per cent. S. in std.}}{\text{c.c. iodine reqd.}}$ and not by means of the theoretical value of each c.c. of iodine in terms of sulphur; then if the standard is 0.103 per cent., and the acid as number 5 above, the factor will be 0.00736. Now, if during a series of tests, and after the standard factor has been determined, a fresh bottle of acid is brought into use, it may be of a purity indicated by 1, consequently, proportionately speaking, any tests made will reveal high, or at least incorrect, sulphur results, since iodine will not be liberated from the iodide and consequently more iodine solution will be used. If the reverse is the case, and the purer acid is used for the standard, then the results will still be incorrect, because they will be lower than the actual if impure acid is used for the tests. The foregoing three points of importance could be exemplified by many instances of causes of incorrect results which have been under the writer's notice from time to time, but space requirements prevent publication of these, but sufficient has been brought out to illustrate likely pitfalls when carrying out the estimation of sulphur by evolution, and to emphasise the necessity for strict attention to such points and to other details.

The writer's view is that the evolution method is an excellent method for routine work, and is accurate in the majority of cases when carried out with care; the safest plan is to standardise each operation in the process so as to cut out as far as possible the human element; the result of such standardisation makes possible with ease an accuracy of 0.005 per cent., and duplicate tests to check within 0.002 per cent.

A New Testing Machine.

A new type of portable testing machine has been designed by Mr. Geo. B. Richards, of 70, Hill Top, West Bromwich, which embodies several novel features. The general appearance of the machine is shown by our illustration. It only occupies about 21 in. square, and is 30 in. high. It weighs 1½ cwt. Though so small, it is capable of testing the standard malleable bar—8 in. long by ⅝ in. dia. at the centre—up to 26 tons per sq. in.



FOUNDRYMEN'S TENSILE TESTING MACHINE.

Obviously it is capable of testing the "S" bar of the Institute of British Foundrymen's tentative specification, and is capable of tackling bar "M" up to 11 tons per sq. in.; whilst the largest bar is incapable of being broken, but, after all, this state of affairs exists in some of the larger standard machines. An elongation up to a maximum of 1½ in. is available.

The machine is to be known as "The Foundrymen's Machine," and its installation should make the small foundry reasonably independent of the outside testing concerns, so far as tensile tests are concerned.

B.C.I.R.A. Appointments.

Mr. G. Murray has been appointed chemist in charge of the laboratory which is situated at 56, Guildford Street, Birmingham. Mr. L. W. Bolton is to be the technical assistant and Mr. H. J. Simcox, B.Sc., has been transferred to the laboratory from the metallurgical department of Birmingham University.

Mr. J. C. Arrowsmith, M.Met., has been appointed to the staff of the Association to work at Sheffield University on special duty irons in conjunction with the present investigator, Mr. E. C. Dickinson, B.Met.

Metal Spraying and Sprayed Metal.*

By T. Henry Turner, M.Sc., and W. E. Ballard.

INTRODUCTION.

Exactly ten years ago a short account was given to the Institute of Metals of an invention which had been protected in nearly all countries during the years 1909-11. This protection related to the method of spraying metallic particles on to any surface by means of a form of pistol. The process was boomed immoderately, and, of course, proved to have many faults when exploited commercially.

This unfortunate beginning in England was due partly to the fact that the invention was of foreign origin, and partly also to the fact that the few Englishmen who had any knowledge of it were called away on war service. Until after the war the process remained practically unknown so far as this country was concerned, but it achieved a considerable degree of success in a number of foreign countries.

To-day it is being worked commercially in England, France, Germany, Denmark, Holland, and Switzerland, and also in the United States, and it appears that in each of these countries the process has succeeded in making progress even during the recent trade depression.

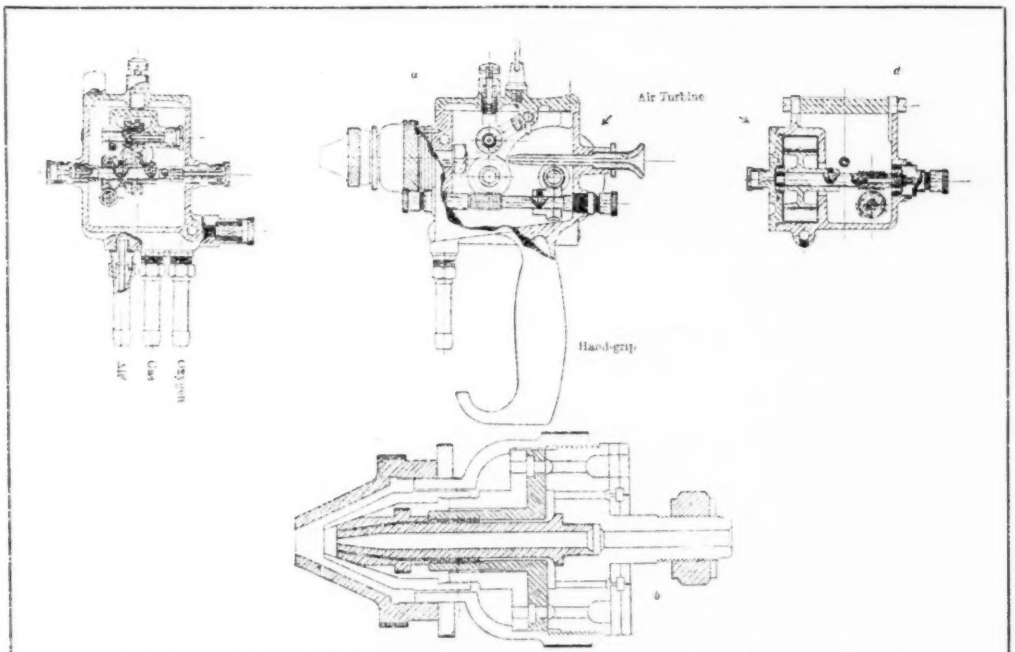


FIG. 1.—DIAGRAMMATIC ILLUSTRATIONS OF A GAS-OPERATED WIRE SPRAYING PISTOL.
(*a*) Side view in part section; (*b*) enlarged view of nozzle; (*c*) cross section through wire feed rollers; (*d*) cross section through air turbine.

The object of this Paper is to indicate the actual capabilities of metal spraying as now practised. Unless otherwise mentioned, the statements made refer to personal observations on the part of one or both of the authors. The investigation has included an examination of the history of the process and of its present capabilities and applications.

Appliances and Operation of the Metal-spraying Process.

The unit of all the metal-spraying processes of to-day is the wire spraying pistol, a small and handy apparatus, similar in appearance to a paint pistol, but differing in its operation and design. One type of pistol used in this country is illustrated diagrammatically in Fig. 1.

The modern pistol works on exactly the same principle as that described in Colonel Morcom's Paper to the Institute of Metals in 1914. The wire is pulled into the pistol and pushed through the nozzle by means of rollers actuated by a small air turbine in the case. The nozzle, which governs the form of the blowpipe flame and the compressed air-spraying cone, has also been improved greatly.

The pistol is fed with oxygen and some combustible gas under pressure, and also with compressed air, which projects minute particles of metal from the ever-melting end of the wire.

Pistols of this type are at present employed on all work, whatever its size, but it can be confidently expected that a pistol capable of spraying more metal in a given time will be used for large surfaces in the very near future.

It may be of interest to remark that experiments with pistols using heavier gauges of wire have, up to the present, been unsuccessful, owing to the difficulty of arranging a blowpipe flame which will melt such wires at a uniform rate and yet allow for the complete pulverisation of the metal as soon as it is molten.

Attempts have been made to use metallic ribbons, but the apparatus has been found to be too heavy and unreliable for commercial use.

The metal-spraying pistol will spray all metals which can be obtained in wire form and which will fuse in the oxy-hydrogen flame. The metal magnesium is an exception to this general rule.

For small articles, such as may be treated in rumbling barrels, a machine is being operated in one works in this country which uniformly sprays with lead the outside of long metal pipes for use in the chemical industry. The interior of tubes may be sprayed by attaching to the ordinary pistol a long adapter, at the end of which a rotating nozzle is fixed. This produces a fan-shaped spray, and is driven by the air-blast used for projecting the metal. Thus, with the same unit, or pistol, tubes up to 12 ft. or so in length may be coated internally, so long as they are of sufficiently large bore to allow the introduction of the rotating end—that is to say, 1½ in. or more in internal diameter. The preparatory sand-blasting of tubes internally presents some difficulty.

The present-day practice is to sand-blast almost every article which is to be metal sprayed, and it is strongly advocated that, where possible, the article to be sprayed be heated. Devices are in use with which heating, sand-blasting, and spraying are carried out mechanically in one and the

* A Paper presented to the London Meeting of the Institute of Metals (slightly abridged).

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same machine, and the production of other such special machines is but a matter of time and of demand. For metal work, sand-blast pressures of about 30 lbs. per sq. in. and hard black flint sands of about 20-mesh grade are recommended. After sand-blasting, the surface should be sprayed at once, to avoid the possibility of contamination with grease and dirt.

The Nature of Sprayed Metal Coatings.

Although the process has been in use for a considerable number of years, little appears to have been known as to the actual mechanism of the spraying process. It was not known whether molten or solid particles actually struck the article which was being sprayed.

In some of his earlier experiments, the inventor of the metal-spray process fired solid bullets and noticed that they adhered to various surfaces. Subsequently, liquid metal was pulverised and projected on to the surfaces, but what happened when wire was melted in the spraying pistol and projected on to a surface was an unsettled question.

By means of metal-spraying glass slips heated to various temperatures we have found that the particles of metal must actually be molten, or become molten at the instant they strike the surface. This is all the more remarkable since it is a well-known fact that any of the common metals and alloys may be sprayed on to thin sheets of paper without even scorching it. The authors believe that the appearance of the particles proves that they were molten at the moment of impact. It is possible that these illustrations may prove of interest to those engaged upon the problem of surface tension in metals. The reason for the formation of the hollow-ring type of particle is not obvious, but

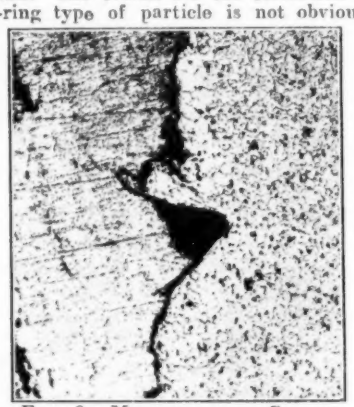

FIG. 2.—MICROGRAPH OF SECTION THROUGH MILD STEEL SAND-BLASTED AND SPRAYED WITH BRONZE. × 100.

probably indicates that the particle was spinning, like a rifle bullet, during its flight.

By cutting a cross-section through a sprayed coating one may observe the union between the foundation metal and the sprayed metal. Remarkably little or no alloying appears to take place. Perhaps we should say this observation comes as a surprise to anyone who has read the inventor's early statements. Sand-blasting produces a vast number of minute pits, some of which retain particles of sand. It is a fact, however, that the coatings applied after sand-blasting do adhere better than those applied to a smooth surface, or even to a surface etched by acid, and, of course, sand-blasting is always carried out in practice.

The explanation of this adherence with little or no alloying is probably very complex, but it is evident that the rough surface does not permit the particles to glance or splash off, or to be forced off by the air stream so easily as with a smooth surface. The full value of the impact is therefore obtained. Cooling is extremely rapid, and probably causes the sprayed mass to shrink on to the projecting portions of the surface. When examining such sections under the microscope, one observes that the sand-blasted surface of the foundation metal is severely strained. This distortion of the surface crystals of the foundation metal may possibly aid the adherence of a coating by encouraging slight movement. Such local deformation, causing a gripping of the sprayed metal, might occur when in contact with hot particles. An example of such a cross-section is shown in Fig. 2, and the uneven sand-blasted surface will be noted. This illustration shows an unusually large piece of sand actually embedded in the mild steel foundation. The coating in this case was one of bronze.

The absence of definite alloying will be observed, and it should also be mentioned in this connection that sprayed zinc coatings are of pure zinc alone, with no intermediate alloy. This is a distinct advantage, as many workers have proved that the iron-zinc intermediate layer formed in hot-galvanising aids the corrosion of the steel base.

The surface of sprayed metal is always matte unless it be subsequently polished. It would be well, therefore, to point out that the chief objection to the use of sprayed metals has been that they have been found to be porous. By careful manipulation of air pressures it is quite possible to spray coatings of tin, lead and zinc that will be absolutely non-porous to liquids. It has, however, been found impossible to make coatings of aluminium, copper, brass, and the higher melting-point metals non-porous by means of the pistol alone. The speed of spraying and the distance of the pistol from the work influence the nature of the coating produced. It has been found possible to metal-spray a piece of metallic sodium with so non-porous a coating of lead and tin that no action occurred when the sprayed sodium was thrown into water.

Methods of Making Coatings Non-porous.

There are, however, three methods which may be, and are, employed in commerce to-day for making sprayed coatings non-porous.

(1) Mechanical work (such as hammering, wire-brushing, or blasting with ball shot) does not give perfect satisfaction and is cumbersome. This method is not used where other methods are applicable.

(2) Non-porous coatings may be produced by spraying on to articles that have been heated to a suitable temperature, depending upon the metal which has to be sprayed. A temperature of 220 deg. C., for example, is suitable for lead spraying. Heating has also been accomplished by encompassing the spraying nozzle with a number of blowpipe jets. This method of making coatings non-porous has been used to a large extent for chemical work.

(3) Very good results have been obtained by precipitating within the pores of the metal an insoluble non-poisonous chemical compound.

Similarly, one may bring about the formation of an insoluble chemical compound in the pores of the sprayed metal by means of a polymeric change in certain mixtures of organic chemicals.

So far as adhesion is concerned, no special tests have been made by the present authors. Other workers in Germany and Switzerland have tested this by at least two methods, but it suffices to say that sprayed metal adheres sufficiently well both to itself and to other metals or non-metals to allow it to be filed. It is thus capable of resisting abrasion to an extent, depending upon the particular metal much as normal metals. That sprayed metal can show considerable resistance to erosion may be gathered from the fact that it is being used successfully as a coating on ships' propellers.

In present-day practice composite coatings are frequently employed, and since the process is much used for acid or corrosion resisting, it is most necessary to consider the nature of the material sprayed and sprayed upon. The composite coatings of more than one metal have given in some cases resistance to corrosion which justifies further use and investigation. For example, zinc followed by aluminium is very suitable in cases of attack by atmospheres containing SO_2. It has been shown that the successful composite coatings are those of metals nearly related in the electro-chemical series. Very good results have been obtained by spraying zinc upon iron and steel objects—this has the advantage over practically all other methods of corrosion resistance, that one can apply it when and where desired over the top of rivets, cold-worked portions, and in general upon part or all of articles which are fully built up. It is unnecessary to stress the point that, in shipbuilding and general engineering constructional work, ordinary galvanising or electro-

plating is of comparatively little value, because the inevitable fracture of the galvanised coating during assembly gives rise to the immediate possibility of serious electrolytic corrosion. Also in case of partial failure of the galvanising, re-galvanising *in situ* is impossible.

Building up Solid Articles by Spraying.

When this investigation was commenced, it was not known whether it would be possible to spray really solid lumps of metal; that is to say, we questioned the homogeneity of sprayed material. In a steel mould, copper, zinc, tin, aluminium, and iron bars were produced by spraying longitudinally for one set of tests, and transversely for a second set of tests. It was found that the bars so produced could all be sawn, filed, planed, turned and machined much in the same way as solid metal. The bars had a clear metallic ring when struck. This latter point was of especial interest to the authors, because it has been stated elsewhere that such bodies entirely lack resonance.

Sprayed metals and alloys do not possess the same hardness values as cast or wrought metals. Tests carried out by investigators in Switzerland and Germany give contradictory data as regards the actual hardness of sprayed metals. This is not to be wondered at, since the method of spraying employed, and the temperature of the foundation sprayed upon, will affect the final product, and also dissimilar methods of testing have been employed. The authors have carried out some hardness tests both upon sprayed coatings and upon solid lumps of material which have been built up by spraying. These tests were carried out in the Metallurgical Department of the University of Birmingham upon metals and alloys sprayed in England under normal working conditions. Hardness figures obtained with the same apparatus on cast materials are given in the following tables for comparison. In the diamond scratch hardness tests the weight upon the diamond was 50 grms. in each case. The ball hardness figures were obtained with a steady load of 10 kg. on 1-mm. ball for 20 seconds.

TABLE I.—*Scratch Tests.*

Metal or alloy.	Cast material.	Sprayed coating.	Sprayed lump tested on top.	Sprayed lump tested on side.
Tin	0.08	0.056	0.055	0.055
Aluminium ..	0.06	0.044	0.048	0.05
Zinc	0.05	0.032	0.033	0.035
Copper ..	0.05	0.029	0.03	0.03
Iron	0.02	—	0.02	0.022
Brass ..	0.05	0.032	—	—
Bronze ..	0.023	0.025	—	—

The figures given are the widths of the scratches measured in mm.

TABLE II.—*Ball Hardness Tests.*

Metal or alloy.	Cast material.	Sprayed coating.	Sprayed lump tested on top.	Sprayed lump tested on side.
Tin	>0.8	0.77	0.8	0.8
Aluminium ..	0.61	0.44	0.57	0.62
Zinc	0.44	0.42	0.55	0.57
Copper ..	0.54	0.38	0.42	0.54
Iron	0.32	—	0.33	0.38
Brass ..	0.54	0.43	—	—
Bronze ..	0.3	0.43	—	—

The figures given are the measured diameter of indentation in mm.

TABLE III.—*Scleroscope Hardness Figures.*

Metal.	Cast material.	Sprayed lump tested on top.	Sprayed lump tested on side.
Tin	5-6	11.5	11
Aluminium	6	12	10
Zinc	12	19	13
Copper	17	50	47
Iron	25	55	45

The figures given were all obtained with the same instrument and the same magnifier hammer.

From Tables I, II and III, it may be seen that, tested by scratch or by scleroscope, the sprayed metal is decidedly harder than similar metal when cast. However, when tested by the ball indentation method there seems little difference between the two, although the sprayed metal is in some cases slightly softer than the cast.

Sprayed metal can be chipped with a chisel without flaking in one direction, but it must be understood that it is liable to flake in another direction. If one takes a bar of this material, which has been sprayed longitudinally, and turns it in the lathe, it will be found that on two sides, the metal is indistinguishable from cast materials. On the other two sides, at right angles to the first, a comparatively rough surface is often, though not always, obtained: this is shown in Fig. 3, which illustrates lumps of copper, tin, and zinc built up by means of metal spraying and subsequently machined by one of the authors. Photomicrographs of sprayed zinc and copper (Fig. 4) were obtained from these samples sectioned longitudinally, and explain the liability to chip in one direction.

From these bars of sprayed material some tensile tests and shock test-pieces were machined.

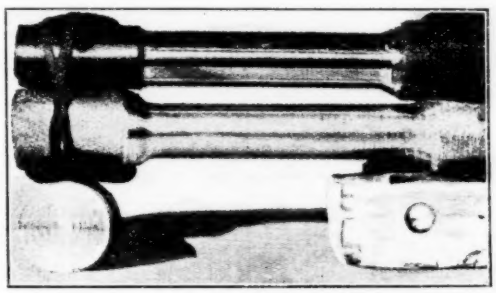

FIG. 3.—LUMPS OF COPPER, ZINC, AND TIN BUILT UP BY METAL SPRAYING AND SUBSEQUENTLY MACHINED.

As would be imagined the strength was very low, but it is still remarkable that it was possible to machine an Izod test-piece from sprayed zinc and to note the difference in strength between the tests taken parallel and at right angle to the laminations. Under a higher magnification one notes that each grain or particle contains many slip-bands all at right angles to its major axis, which is practically parallel to the surface sprayed upon. The grains are therefore in a severely strained condition. The 10-mm. ball Brinell machine was tried on all of these metals and produced bright mirror-like indentations of just the same type as is produced on cast metal. Thus it would seem that the metal-spray process may be used for building up worn parts or for filling up undesired cavities, and that it can give reasonable adherence and mechanical strength when so used.

Sections were cut from these sprayed bars for density measurements and the results of these are given in Table IV.

TABLE IV.—*Density Figures for Pure Metals and Sprayed Bars.*

Metal.	Pure Metals. Hoyt's figures.	Sprayed Metal. Authors' figures.	Sprayed Metal. Arnold's figures.
Aluminium	2.56	2.4	2.3
Zinc	7.0	6.4	6.3
Tin	7.3	7.1	6.8
Iron	7.86	6.5	—
Copper	8.65	8.0	7.5

When one considers the nature of the material, built up as it is of interlocked particles, each of which might have been oxidised, the low density figures are no longer remarkable. One may indeed be surprised that they approximate so closely the figures obtained on cast metals. The fact that the authors' figures are somewhat higher than those obtained by Arnold is probably due to improvements recently introduced into the technique of metal spraying.

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Efficiency of the Process.

In a commercial process such as this, the consumption of wire, compressed air, gas, and oxygen is of importance, and it will be well briefly to consider their relationship so far as it is known.

Considered as a melting furnace the pistol is very inefficient, for only one-fortieth of the heat generated is actually utilised in melting the metal. The rest of the heat is carried away by the expanding air stream. Naturally, the speed of working the pistol depends partly on the melting point of the metal in question, but it is possible to vary this speed within certain limits. There is, however, in all probability a definite speed at which the best results will be obtained for any metal, for by obtaining the correct speed for lead, tin, and zinc it has been found possible to spray coatings of these metals that are non-porous to liquids.

The wire consumption per hour is given in Tables V and VI. Table VII shows the consumption of oxygen. When using coal-gas with oxygen it is found that the amount of coal-gas used is 1.5 times that of oxygen (*i.e.*, when the calorific power of the gas is about 450 B.Th.U. per cub. ft.). The amount of hydrogen actually used is 2.8 times that of the oxygen, or more than that required theoretically. When using acetylene the oxygen figures multiplied by 0.75 give the consumption of the acetylene.

TABLE V.—*Wire Consumption, Using Coal-Gas.*

Metal.	Diameter of wire Mm.	Metal sprayed per hr.	Metal deposited per hr.
		Lb.	Lb.
Lead	1.5	14.0	11.0
Tin	1.5	6.0	4.5
Zinc	1.0	4.5	3.5
Aluminium	1.0	1.25	1.0
Copper	0.8	1.125	0.875
Bronze	0.8	1.125	0.875
Brass	0.8	1.25	1.0

TABLE VI.—*Wire Consumption, Using Hydrogen.*

Metal.	Diameter of wire. Mm.	Metal sprayed per hr.	Metal deposited per hr.
		Lb.	Lb.
Lead	1.5	16.0	12.5
Tin	1.5	7.5	5.25
Zinc	1.0	5.5	4.25
Aluminium	1.0	1.5	1.25
Copper	0.8	1.25	1.00
Bronze	0.8	1.25	1.00
Brass	0.8	1.375	1.125

TABLE VII.—*Oxygen Consumption with Hydrogen as the Combustible Gas (in cub. ft. per lb. of metal sprayed).*

Lead	2.64
Tin	2.86
Zinc	5.32
Copper	10.82
Nickel	14.6
Iron	17.4
Aluminium	22.7

The approximate consumption of oxygen with other gases is given by the formula :—

x = consumption of oxygen per lb. with hydrogen.

$x \times 1.7 =$,, ,, ,, coal-gas.

$x \times 0.8 =$,, ,, ,, acetylene.

The air pressure used in England is usually about 45 lb. per sq. in., whereas on the Continent it is usual to employ a pressure of 35 lb. The higher pressure used in England has been found to be an undoubted advantage when spraying lead, tin, and zinc, but it would no doubt be better if the air pressure were varied with the metals being sprayed. The higher pressure of 45 lb. per sq. in. should be used with tin, and the lower pressure of 35 lb. per sq. in. used when such metals as copper are sprayed.

Uses of the Process.

The process is at the present time used in France and Germany to a considerable extent on shipping work, and for the protection of overhead transmission line poles and wireless masts for big stations. It is being increasingly used in this country for the protection of certain portions of ships and for propellers. Both wooden and steel bulkheads are being coated with zinc in many shipyards.

It was largely used in Germany during the war for protecting shell parts from corrosion, and proved much more effective than electrolytic zincing. It is also used there very successfully to replace the usual copper cable rail connectors on electric railways, so that at present on the Berlin and Hamburg underground railways one may see miles of rail without a copper connector.

This application is worth special mention, because up to the present it does not appear to have been introduced into England. During the war, when copper was scarce in Germany, the copper cables were removed from the electric railways in Berlin and electric connection between the two rails secured by sand-blasting *in situ* the rail ends and the inside surfaces of the fish-plates. These surfaces were then immediately sprayed with zinc, and when bolted together again gave excellent electrical contact, and apparently they have been satisfactory ever since. The electrical resistance of this type of joint has been found to be even less than with the best copper cable joints.

It has thus become the practice of the Siemens-Schuckert works to install this type of joint in place of the customary one. Doubtless this practice will be introduced into England when the nature of the joint is appreciated by electrical engineers.

There are very many uses which can only be set down in summary. Among these are the protection of the steel of vulcanising pans, protection by tinning of tanks intended for foodstuffs, and the coating with zinc or aluminium of containers intended for crude or light oils.

Another use of the aluminium coating is that of protecting iron from oxidation at high tempera-

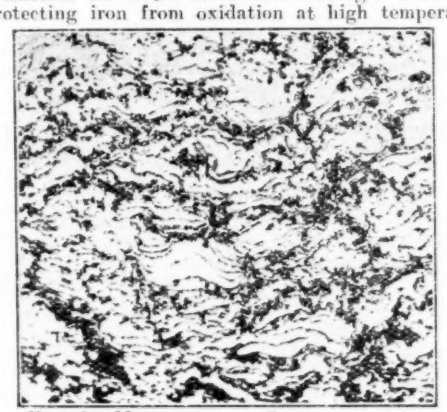


FIG. 4.—MICROGRAPH OF SECTION THROUGH SPRAYED COPPER. × 100.

tures. This has been carried out very successfully in France, Germany, and England. Two methods are available—the first and best being that of spraying aluminium on to the iron at a red heat after it has previously received a very thin coating in the cold state. The second method is by spraying the aluminium cold and then transforming some of the metal into oxide by the use of chemical reagents.

In England to-day several firms have proved these methods to be excellent, but it has been found that while they are successful against flue gases and high temperatures they are not to be recommended in furnace atmospheres which contain metallic fumes, especially fumes of zinc.

In conclusion, the authors call to mind the warning given by Professor Turner in his Presidential Address, to the effect that the world's supplies of metals are by no means inexhaustible. The prevention of the present wastage of metal by corrosion is essential. They believe that the metal-spray process is capable of aiding considerably in the preservation of the world's metallic treasures now corroding and burning away in railroads, ships and furnaces.

Their thanks are here offered to Professor T. Turner for permission to investigate this process in his laboratory; to Mr. G. A. Shires, B.Sc., for assistance with the scratch hardness tests; and, finally to Mr. W. J. Thompson and Mr. A. A. Arnold of Metallisation, Limited, for very kindly supplying information and material.

A Comment upon the Methods of Judging and Mixing Pig-iron.

Mr. Young Replies to his Critics.

Mr. Pearson asked if English pig-iron were better than foreign. He (Mr. Young) thought that English and Scotch pig-irons, as a class, are superior to others; he knew that some foundries abroad use little else than British iron when doing more important work. One obstacle to the supremacy of our pig-irons is the out-of-date and unscientific methods of many merchants. Claims of liquidity, strength, wearing and heat-resisting properties, coupled with absence of guarantee as to constancy of composition are detrimental to our products. The continental foundryman is capable of looking into the truth of these matters. An honest scientific statement would, nowadays, sell more pig-iron and inspire more confidence than claptrap. Those desiring to do business on the lines that no matter how much the iron altered from consignment to consignment the purchaser must have faith in the metal retaining the properties set forth in their booklet, would need to do it quickly, because the generation now growing up are wise to the actual facts of the case.

Mr. Faulkner said that he (Mr. Young) represented pure science, but this present Paper consists of the plain statement that a properly-controlled foundry has no use for fracture-divining and can make castings alike in composition and physical properties year in and year out.

The contributor who called him (Mr. Young) a lead pipe swinger forgets the futility of re-naming the rose, and that the use of such phraseology brands the user.

He (Mr. Young) is pleased to find Mr. Buchanan in agreement with him. To quote Mr. Buchanan's own words: "The chemists should put their house in order. *Then they might be able to rely on the doctrine that with similar analyses they could obtain similar results.*" It could not be expressed better; Mr. Buchanan's belief is precisely what the author's Paper states to have been proved to be a fact. It is obvious also that Mr. Buchanan wishes that it were not true.

Mr. Poole says: "The writer seems to have forgotten one simple and important thing, namely, co-operation. *In two previous Papers* he (Mr. Young) has stressed the matter of co-operation." Mr. Poole goes on to say that "He made invaluable use of the fracture, but took care to back it up by analysis." He (Mr. Young) found that the vision of Mr. Poole making invaluable use of the fracture but taking care to back it up by analysis left him (Mr. Young)—colloquially speaking—very cold. Mr. Poole demonstrates a lack of correlative appreciation of the relations between composition and cooling conditions on the one hand, and fracture and physical properties on the other.

Later, Mr. Poole says that he did not mean his remarks in a personal sense. Mr. Poole forgets that the more the truth is attacked the better for it. Selling, choosing and mixing pig-iron by fracture is, for first-class work, a thing of the past. Too much of fracture-divining, fortune-telling, star-gazing and so on, depended upon the ignorance superstition or plight of the client.

He thanked Mr. Gallon for his kindly remarks, particularly those regarding co-operation. Fortunately he (Mr. Young) has no experience of the iron-foundryman who would not work with him. It is time the chemist came off his perch and told the foundryman the truth without pandering to any spectacular performance, like fracture-divining.

Mr. Fletcher's remarks are particularly valuable in that Mr. Fletcher has personal knowledge of the Paper being a statement of fact, as he (Mr. Young) found it to be. The more we understand the composition of cast iron the more are we able to control and improve its properties; analysis tells us what is in it, and in what quantities, whilst the microscope shows how those things occur. Fracture-diviners have had a long reign, and the ignominious position of grey cast iron, as compared with that of other metals, is due to it. Even those diviners of enormous experience at ironworks are unable to deliver consignments of iron alike or nearly alike, as has been proved in a past Paper by the present writer.

Mr. Cook says that the Paper does a great injustice to the chemist for condemning slack methods, which provides a neat paradox to Mr. Buchanan, who says their methods are terribly slack. Mr. Cook's point-of-view here is limited, and he (Mr. Young) has the advantage of many years' experience as an analyst in several laboratories, and, later, as one whose work depends upon the accuracy of analysts.

Mr. Cook says that he (Mr. Young) had never been able to give an answer to a certain research on a case where two irons, said to be of identical composition, possessed different physical properties. Considering that the research was conducted by Mr. Cook, it seems unfair to blame anyone else for not solving the problem. He (Mr. Young) finds that the majority of pig-irons behave in accordance with the laws discovered by Keep, Turner, Stead and others; thus far he had come across no exception. Exceptions there would be, however, and much might be learned from them. Meantime, we can control our foundries along scientific lines and make use of new knowledge as discovered.

Mr. Marks appears to agree with the substance of the Paper, but he, like several other contributors, does not recognise certain things as axiomatic. Firstly, co-operation is essential; secondly, a foundry cannot be controlled by *wrong* analysis; thirdly, the analysis, when done, must be dealt with by somebody who understands it; fourthly, he (Mr. Young) is aware of the reactions of the cupola; lastly, the cupola cannot better be controlled by tuyere-gazing than can pig-iron by fracture-divining. Many things are essential to success, including a knowledge of one's own ignorance; the writer's little Paper was an effort to inform the world at large that castings constant in composition and in physical properties could be made more certainly by scientific control than by any system, complete or partial, of fracture-divining. His proof is not a scientific one but a practical one, namely, that he does it.

Mr. Rowe writes an appreciation of the author's remark regarding the necessity for carbon control. Further, he says: "The variation in fracture due to the causes enumerated by Mr. Young, is not so great as he would have us believe." This is a serious statement for the fracture-diviner, because *we know the iron varies greatly*, and now we are learning that *the fracture does not*. Mr. Rowe says he checks his analysis by fractures, but Mr. Poole said he checked his fractures by analysis. Presumably, therefore, if Mr. Rowe finds by analysis that a pig contains, say, 3.71 per cent. carbon, 2.53 per cent. silicon, 0.89 per cent. phosphorus, 0.067 per cent. sulphur, and 0.64 per cent. manganese, and he looks at the fracture and the fracture says the analysis is wrong, *Mr. Rowe rejects the analysis*. But Mr. Poole looks at the fracture, and if the analysis says the fracture is wrong, *Mr. Poole rejects the fracture*.

Mr. Rowe asks for the methods adopted by him (Mr. Young) for estimating the various forms of carbon in cast iron. Almost from its commencement has Mr. Young been a co-operator in the movement for the supply of standards known as British Chemical Standards, and if Mr. Rowe is interested in the difficulties of obtaining accurate analyses he will gain information by communicating with Mr. C. H. Ridsdale, F.I.C.

Another contribution is that of a foundryman who says Mr. Young's views represent the ultra-scientific side of the question. There is nothing "ultra" about judging a metal by its composition, to do so is more commonsense than gazing at the fracture and using the mixtures of one's grandfather. "I am not a chemist," he says, "therefore I do not know what effect this addition (i.e., of silver) would have in the casting," which remark goes to prove that the previous part of his communication, extolling the foundryman's knowledge of metallurgy, is a matter of habit rather than of fact.

Mr. Field writes: "Mr. Young lent himself to a startling condemnation of the puerile efforts of small laboratory staffs," but he (Mr. Young) has done nothing of the kind. Mr. Field says he is amused at the lack of agreement between some thousands of analysed test bars, and states: "I make bold to suggest that his test bars often contain the same components in the same propor-

tions." Mr. Field should consider the calculation showing the number of chances against two casts giving two test bars precisely alike in combined, graphitic and total carbons, silicon, phosphorus, sulphur, and manganese. To make two cupola-melted grey cast irons alike—in the "scientific-research" meaning of the term—is a feat which he (Mr. Young) has not accomplished. Mr. Field is not alone in confusing two entirely different problems. To control an iron foundry so that castings of similar composition and properties are turned out time and time again is a different proposition from making two test bars alike in that the one gives precisely similar tests to the other. The former is a problem already solved; the latter is so difficult that it cannot be done with certainty, even when the bars are cast *from the same ladleful of metal*. Moreover, the difficulty is not peculiar to cast iron, being met with in test bars of any cast alloy, aluminium, gunmetal, etc. These points should not need emphasis; every scientifically-trained person is aware of the many factors operating against the making of two things precisely alike; even in Nature, so far as can be ascertained, it rarely happens. It is an interesting subject, but one with which the Paper did not deal.

Mr. Adamson says he (Mr. Young) "will not accept the ordinary commercial analyses of pig-irons and cast irons." If Mr. Adamson is referring to the analyses given in many booklets issued by pig-iron merchants, the statement is a platitude; *the merchants themselves will not accept these analyses*, and state so plainly—often in red ink. Mr. Adamson's contribution to his (Mr. Young's) Paper entitled "The Problem of Grey Iron Castings," in which the records of many pig-irons over a number of years were given in full, refutes Mr. Adamson's present statement that he (Mr. Young) has failed to give *proofs* of the correctness of his views. Moreover, there is no question of "views": it is a matter of modern *versus* ancient foundry practice.

Mr. Adamson is one of those to whom the news of two test bars of apparently similar composition giving different tests acts as a stimulus to renewed arguments against controlling cast iron along those lines which have proved successful in all other metallurgical industries.

Mr. Adamson's final comment that "Hence it will be seen that Mr. Young is unwittingly working on fracture as well as chemical composition," is by reason of the word "unwittingly" a remarkable innovation. He adds, "which is the whole case of the physicist," but it looks more like that of the spiritualist. Mr. Adamson also confuses the two subjects referred to in the reply to Mr. Field and others.

To quote the late Dr. J. E. Stead's address before the Iron and Steel Institute only four years ago. . . . "Few can conceive what prejudice existed a few years ago in the minds of those who controlled the mixing of metals in the iron foundries. These gentlemen did not realise that although the fractures of the pigs they used might be the same in different consignments from any single firm of pig-iron makers, the composition varied to a considerable extent, and that corresponding variations resulted in their castings. . . . It is now generally admitted that the peculiar properties of every brand of iron are due to differences in composition."

The Effect of Progressive Cold-rolling on the Brinell Hardness of Copper.*

By H. Moore, O.B.E., D.Sc., Ph.D.

Summary.

In a Paper recently published by Rawdon and Mutchler, of the Bureau of Standards, U.S.A., it is stated that in the cold-rolling of copper, iron, tin and other metals and alloys, the Brinell hardness rose rapidly during the initial stages of deformation and then diminished; "the metal becomes softer and in its final form may be softer than the metal in its initial stage." Experiments have been carried out at the Research Department, Woolwich, to test this surprising conclusion. An annealed copper bar was cold-rolled from 3.12 in. to 0.0125 in. thickness, one-half of the material being withdrawn for testing after each reduction of 50 per cent. of the thickness. The Brinell hardness number was 48 in the annealed bar, 98 after the first reduction of 50 per cent., rose at each subsequent reduction, and reached 130 when the thickness was reduced to $\frac{1}{250}$ of the original thickness. Balls of 5, 2, 1 and 0.8 mm. diameter were used in the Brinell hardness tests, care being taken in testing the thinner strips to avoid error arising from the use of too large a ball and load. The results give no support to the suggestion that severe cold-rolling of copper beyond a certain stage induces softening, and the author considers that convincing evidence of any such effect occurring generally in metals and alloys is still lacking.

* A Paper presented at the Autumn Meeting of the Institute of Metals.

Investigation of the Effects of Impurities on Copper.*

Part II.—The Effect of Iron on Copper.

By D. Hanson, D.Sc., and Grace W. Ford, B.Sc.

Summary.

Iron has been shown to exert a very considerable effect on the properties of pure copper; the effect of this impurity is, in many respects, very much greater than that of oxygen. The observed effects on the mechanical, electrical, and other properties are in keeping with the structure and constitution of iron-bearing copper, as revealed by a microscopical study of this material. Solid copper will dissolve about 4 per cent. of iron at 1,100 deg. C., but the solubility at lower temperatures is much less. Within the limits of solid solubility the effect of iron is considerable, particularly on the electrical resistivity, which increases rapidly as the iron content is raised; this increase is so rapid that iron must be regarded as extremely deleterious in copper for electrical purposes. When the iron content exceeds about 0.2 per cent. the effect on the resistivity depends largely in the heat-treatment of the material.

The effect on the tensile strength is less than might have been anticipated in the case of a soluble impurity, and although in this respect iron has more effect than oxygen, it still produces a relatively soft material, even when the copper is saturated with iron. The tensile strength is raised by 2 per cent. of iron from 14.5 tons per sq. in. to about 20 tons per sq. in. The effect of heat-treatment is relatively small, in spite of the large differences in solubility of the iron, and a considerable improvement in strength as a result of heat-treatment, such as can be obtained in steel and some aluminium alloys, has not been realised. The relatively small effect of the "iron" constituent on the strength is possibly due to the fact that this constituent is essentially metallic iron (containing some dissolved copper), and does not itself possess the great strength and hardness of intermetallic compounds, which usually have a more considerable effect on the mechanical properties.

Iron has no great embrittling effect, and copper containing iron can be rolled with ease. In the material "as rolled" the strength and ductility after 60 per cent. reduction are the same for all the material except that containing the lowest amount of iron, and the large reduction of area when this material was tested suggests that the ductility is far from exhausted after this amount of work.

Iron is a deoxidiser for copper, but it creates difficulties during casting, owing to the formation of films that destroy the continuity of the metal. The deoxidising action is not great, as a considerable excess of iron would appear to be required to remove all the oxygen.

Copper containing iron as a sole impurity is difficult to machine; it is soft, and "drags" under the tool.

* A Paper read before the Autumn Meeting of the Institute of Metals.

German Foundry Practice.

At the recent International Foundry Trades Exhibition, held at Bingley Hall, Birmingham, Dr. Werner, the President of the German Foundrymen's Association, addressed a large audience on recent advances in foundry practice.

Dr. Werner said he was particularly interested in the improvement of the cupola process, because he had always firmly believed that the cupola was the most neglected part of manufacturing processes in the foundry. They would find that the amount of coke used in the average cupola practice was enormous in comparison with the amount actually needed. When Mr. Schurmann invented the new side blast cupola, which was connected with a pre-heating system, he was unable to persuade anyone to try out his invention. Finally, his (the speaker's) firm decided to erect a furnace according to Mr. Schurmann's ideas. At first they had no great confidence in the innovation, but it was true to say that from the first day of the running of the cupola with side blast and pre-heater they found that every claim made by Mr. Schurmann was fulfilled. The invention consisted practically in adding a chamber composed of two parts. As a result it was possible to send the blast from the blower through one part of the chamber and thence horizontally through the cupola. It then passed up the other part of the chamber and into the air. They then reversed the blast, directing it through the second chamber, which had been pre-heated by the gases of the cupola. The blast again passed horizontally through the cupola and up the other chamber, afterwards going into the air. They reversed the blast every eight, ten, twelve or fifteen minutes, to suit the conditions. The amount of blast blown through the cupola horizontally into the regenerator amounted to about 50 to 60 per cent., while 40 to 50 per cent. of the blast passed up the cupola shaft vertically just as it did in a standard cupola. To increase the amount of air passing through the cupola horizontally they could put a lid on the cupola and have a small stack coming out of the cover, so that with the stack from the regenerator or pre-heater there were two small stacks coming through the roof of the foundry instead of the big stack of the cupola passing through the roof. These two stacks passing through the roof had nothing but some light blue smoke coming out, while the temperature on the charging platform was so low that it was possible to put one's hand right into the cupola without danger. When the first Schurmann cupola had been installed in his country, they wanted to know the scientific basis of the invention, and they started on experimental work. This had kept them busy for a long time on account of the difficult conditions which had to be faced in the works during 1923. During the experimental running of the cupola temperatures were taken, and at the same time analyses of the gases. Altogether they had made more than 2,004 analyses of gases and taken about the same number of temperature records. These figures had been examined, and it was his intention to give his hearers the final results of the experimental tests.*

Results Examined.

In the foundry there were two cupolas, both of the same size, one of which was converted according to the system of Mr. Schurmann, with a pre-heater attached to it and side blast brought into the cupola. They started testing with a charge of coke giving the ideal working condition for the standard cupola and the Schurmann cupola. It was found that the best working condition for the standard cupola required 13 per cent. of charge coke, whereas the Schurmann needed only 8 per cent. The bed coke of both cupolas was the same. The volume of air needed for the Schurmann cupola on the basis of 8 per cent. of charge coke was 2,611 cub. ft. The theoretical amount was figured out at 2,540 cub. ft., so that the amount of air needed for the Schurmann cupola was almost theoretically the right one. In the case of the standard cupola the amount of air ought to have been 2,928 cub. ft., but as a matter of fact the cupola had to have 4,660 cub. ft. to keep it in perfect running order. The different measurements showed that the temperature of the molten iron out of the Schurmann cupola was 50 to 60 deg. C. higher than out of the standard cupola, and the running slag during the melting time 80 to 100 deg. C. higher. As indicating the scope of the tests and experiments, he mentioned that as to the raw materials analyses were made of the pig, scrap, coke and the remaining coke after the melting time closed and of the limestone and of the ganister. They cast test-bars from different taps, the running slag was analysed and the dump slag. Gas analyses were taken in the chambers before the gases entered the regenerator. The gases were also analysed at the exit of the regenerator and above the tuyeres at various heights, and finally on the charging floors. Temperatures were taken first at the blower, then at the entrance of the air into the regenerator, and of the heated-up air before entering the cupola. The temperature of the gases was taken before entering the regenerator and at the exit of the regenerator. The temperature of the cupola was taken by means of peep-holes with a pyrometer, also at 20 ins. above the tuyeres and at two other heights. The iron in the ladle was tested, the temperature of the slag was taken as well as of the shell of the cupola and the shell of the regenerator. The weights were taken of the bed coke, the charge coke and the dump coke. Other tests were:—The weight of the charge and the weight of the molten iron, the weight of the slag, the running slag and the dump slag, the volume of blast at the blower, the volume of the gases at the charging floor, the volume of the gases at the regenerator. The inner diameter of the cupola was measured before the melting time and after, the pressure of the blast before entering the cupola and the energy of the blower. As to mechanical and physical properties, transverse, compression, impact resistance, and shrinkage tests were taken. In addition, there were tests to determine the amount of gases, and especially the free oxygen, and finally metallographic tests. Personally, he had the feeling, after the report on the experiments was furnished, that everything possible had been done to find out all about the working conditions in the Schurmann cupola. The coke of the Schurmann cupola gave the following analysis:—Carbon, 80.26; iron, 1.26; sulphur, 1.29; ash, 10.48; moisture, 6.76; and the coke of the standard cupola, carbon, 80.19; iron, 1.21; sulphur, 1.30; ash, 10.40; moisture, 6.70. The run of the two cupolas on the date reported was 158 minutes for the Schurmann and 141 minutes for the standard cupola. The amount of charge coke saved by the pre-heating system and the side blast amounted during that time to 51½ per cent., and if they took the bed coke into consideration the saving was 22 per cent. The increase of thermal efficiency of the Schurmann cupola as compared with the standard cupola was 28.7 per cent. With reference to the mechanical properties of the iron from the Schurmann cupola in comparison with the standard cupola, these had been subjected to a large number of tests and with widely different kinds of iron. The first was cast iron for cylinders, then for thin wall pipes, then silicon-cast iron, and finally cast iron for jobbing castings. The tensile test gave the following results:—

	Schurmann cupola. Tons/sq. ins.	Standard cupola. Tons/sq. ins.
Cylinder	27.40	24.5
Pipe	24.95	21.33
Acid-resisting C.I.	23.74	22.30
Jobbing	23.35	21.20

The Brinell hardness figures were:—

216	210
230	220
198	196
207	206

The impact tests showed:—

Ft. lbs./sq. in.	Ft. lbs./sq. in.
28.00	24.25
22.87	15.87
26.60	22.87
28.90	23.33

* For details of experiments see "Die Giesserei," No. 19, July, 1924, pages 426 to 429.

Oxygen in Cast Iron.

The compression test showed for the Schurmann cupola 5020 to 5500 against 4660 to 5230 in the case of the standard cupola. The microstructure of the iron out of the Schurmann cupola showed a finer grain, the cause being the greater amount of free oxygen contained in the cast iron. The amount of free oxygen in cast iron out of the Schurmann cupola was 0.148 to 0.158, compared with 0.071 in the standard cupola iron. The shrinkage of the cast iron was higher from the Schurmann cupola, amounting to 0.90 to 1.12, against 0.85 to 0.99. The tests gave as their final result that the Schurmann cupola had a thermal efficiency about 30 per cent. higher than the standard cupola. The losses in silicon, manganese, etc., were the same, but the loss in carbon was higher in the Schurmann than in the standard cupola. The molten iron was higher in temperature by 50 to 60 deg. C., and the slag by 80 to 100 deg. The amount of free oxygen in the Schurmann iron was higher than the standard cupola iron, and therefore the mechanical properties of the Schurmann iron were better. At another foundry where the Schurmann system was installed the foundry manager had made tests of his own and had supplied very interesting figures. At this foundry, also, they had two cupolas of the same size which were supposed to have a ratio of 8 to 9 tons per hour. This foundry manager found that he was able to run the Schurmann cupola with great flexibility. He started at the melting time with a melting ratio of about 6 tons and increased the output of the cupola up to 15 tons per hour when the foundry floor required that amount of iron.

Coke.

The coke used in this foundry was of poor quality and had 10 per cent. ash and 1.1 per cent. sulphur. The temperature of the liquid iron was usually about 1,410 deg. C. from the Schurmann cupola, whereas it required quite a considerable amount of trouble to obtain iron of that temperature out of the standard cupola. Eighty tons of iron was melted daily. The gain in sulphur in the case of the Schurmann cupola was reported to be between 1.9 and 14.6 per cent., whereas the gain in the case of the standard cupola was 27.9 to 92.4 per cent.* The sulphur content of the iron out of the Schurmann cupola amounted to between 0.05 and 0.064 per cent., and out of the standard cupola to 0.09 to 0.124 per cent. The charge coke never exceeded 8 per cent. with the Schurmann cupola, whereas with the standard cupola it was always between 13 and 14 per cent. For the standard cupola the blower had to supply 5,292 cub. ft. at 35.4 in. blast pressure, while with the same melting capacity the Schurmann cupola needed only 3,884 cub. ft. at a blast pressure of 13.8 to 19.3 in. The cupola had an inside diameter of 44 in. The amount of limestone used was also reduced. The foundry manager made a special investigation into the cost of melting in both cupolas, and found that per ton of iron the cost, in the case of the standard cupola, amounted to 7s. 6d., whereas with the Schurmann cupola it was only 5s. 2d. He also laid stress on the fact that he had been able to run the Schurmann cupola with a larger amount of scrap in the iron charge than with the standard cupola. He hoped he had convinced his hearers that he was right when he said that Mr. Schurmann's invention was the first real step in the improvement of cupola practice since their introduction.

Pouring Temperature.

Dr. Werner referred to pouring temperature, remarking that if they examined the literature on the subject and tried to find out exactly how the pouring temperature influenced the different properties of cast iron, they would discover that very little had been written on the subject. He proceeded to show slides indicating the results of recent investigations,† and said that the future of the oil engine, for instance, would necessitate the provision of cast-iron that would stand the great differences in temperature and the stresses which occurred during the running of a Diesel engine.

Dr. Werner described attempts to make good cast iron without good pig or scrap, stating that first of all they tried to get the silicon better into the cast iron than formerly. This led to the use of the so-called silicon packets. In the same way they had made phosphorus and manganese packets, which were added to the molten metal in the ladle, and the results had been very satisfactory. Sometimes they were even used by charging them into the Schurmann cupola, also with good results. Desulphurising became an important matter, because in the years immediately following the war, German pig-iron always contained a large percentage of sulphur. A mechanical engineer living at that time in Austria at first advised the use of potash as a desulphuriser.* He went to great pains to discover the right method of making the addition, and one of the first things he required was that the iron should be absolutely free from slag. But in skimming off the slag and adding the potash, gases were developed which the man at the ladle could not stand. Therefore this process was at first confined to those cupolas which were equipped with receivers, and the practice was to connect the covers of the receivers with the stack and to the open air so that the gases could be carried off. This, however, did not give very much satisfaction at the foundries which were using the innovation, and a consulting engineer for foundry work brought out a patent system of a slag retainer to be connected to the receiver. At the same time there was introduced another patented system, by which the slag was skimmed off at the spout of the cupola by forming a syphon chamber just before the spout. In this manner the iron out of the cupola ran into the receiver perfectly free from slag. The addition of the potash then had the effect that the amount of sulphur was greatly reduced. As a result, certain foundries which had installed the Schurmann preheating system were also adding this process to the Schurmann cupola, especially foundries connected with engineering firms, because the machining quality of the cast iron was very much improved, often more than 30 per cent.

In closing, Dr. Werner said that in his country they greatly appreciated the work of the British Cast Iron Research Association. They were also working in the Iron and Steel Research Institute at Dusseldorf, and he hoped the work done in all the research institutes of the world would soon be mutually exchanged.

Discussion.

Opening the discussion, MR. F. J. COOK said Dr. Werner had made out a strong case with regard to the economy resulting from the methods he had advocated, and also as to the beneficial effects upon the metal produced. As to the measurement of blast volumes, he hoped that when the paper was printed the formulas used would be given in determining the quantity of air. He also hoped it would be stated whether the height of the barometer and the temperature were taken into account. He was very much struck by the composition of the coke used. In this country we had been complaining very much since the war of the very bad quality of coke supplied. However bad our coke had been, the German coke seemed to have been very much worse. Some of the figures given—1.29 and 1.3 sulphur and only 80 per cent. of fixed carbon—we should consider very bad indeed, and if in Germany in spite of such coke they could produce good castings, by adopting the Schurmann cupola, in this country we ought to be able to get good results from sows' ears. Dr. Werner also referred to the fact that the German cupola produced a closer grain. That was a very vague term, and he would like to know whether Dr. Werner had some means of measuring the size of grain. Did he measure the average size of the graphite in area, length and width, because the question of fine or coarse grain was quite an elastic term. It was quite easy to take those measurements, and he (Mr. Cook) was rather interested in the size and shape of graphite in its

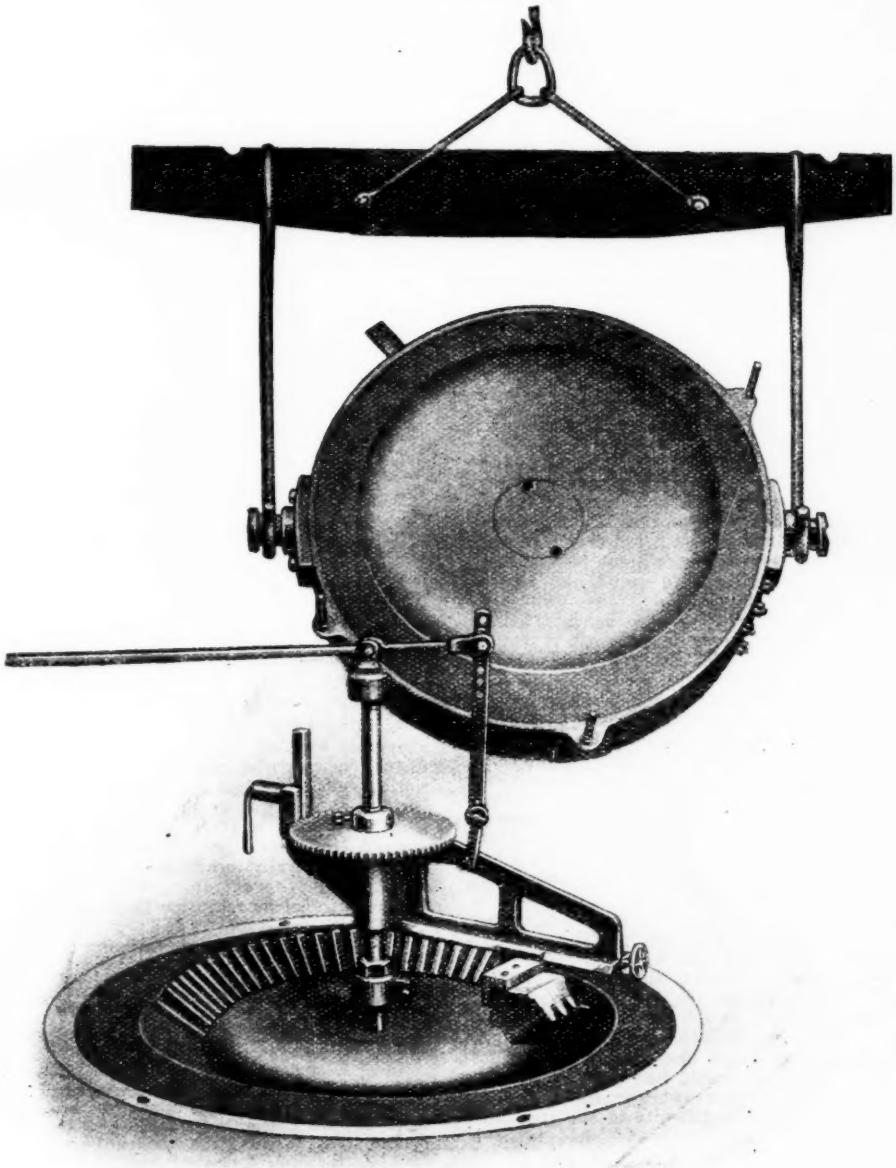
* "Die Giesserei," June 21, 1924, pages 376-377.

† See "Die Giesserei" No. 38 and 39 of 1923, Oberhoffer and Stein "Ueber den Einfluss der Giesstemperatur auf die Eigenschaften von grauem Gusseisen," and "Stahl und Eisen" No. 5, January 31, 1924, Oberhoffer "Ueber Gas- und Sauerstoffbestimmungen in Eisen insbesondere Gusseisen."

* "Die Giesserei" No. 12, 1923.

The "VULCANIA" PATENT WHEEL MOULDING MACHINE.

Patent No. 5049.



THE "VULCANIA" PATENT WHEEL MOULDING MACHINE is for moulding spur wheels with straight, sloping or Vee-shaped teeth, also bevel wheels, skew gear wheels, worm wheels and internal wheels. The machine head is carried on a pillar which is held in a base-plate bedded in the floor sand, and is made to slide on the pillar by means of a lever and link carried on a joint bearing, or by rack and pinion, or screw if thought advisable for the particular work it is being used for.

An adjustable stop collar is provided for accurately deciding the depth of mould. On the removable head a slide is carried for supporting the patterns of the teeth to be moulded. This slide is made adjustable by screw or pinion gearing to the diameter required. The number of teeth to be moulded is decided by a special dividing plate into which a steel wedge or finger engages. The special dividing plate has milled vees, at the angle of 60° inclusive, around its circumference, to receive the steel wedge, which is adjusted by a screw having an internal spring to keep it in tension and to lock the head when ramming operations are being carried out.

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bearing upon strength. Another question in which he was greatly interested, and as to which he hoped details would be given in full in the printed paper, was the question of the measurement of free oxygen. He believed that when we could accurately measure the oxygen and estimate its effects upon iron we should have gone a long way towards eliminating the troubles they experienced to-day. Dr. Werner gave figures showing that there was a greater loss of carbon with the one cupola than with the other, and one would almost immediately infer that that was a question of oxidation. He (Mr. Cook) had been preaching for many years total quantity of carbon in cast iron and its effects, and he had produced iron where he had been able to lower the total quantity of carbon to an appreciable extent without loss of silicon due to oxidation. If the cupola described could be relied upon to reduce the quantity of total carbon present to any appreciable extent without oxidation, or excessive oxidation, it would be a great advantage. Dr. Werner also spoke about the "enormous" differences of temperature in Diesel work. He would like to know if Dr. Werner had any details of the enormous differences that occurred in the temperature in the heads of Diesel pistons.

High-Silicon Iron.

MR. J. G. PEARCE (Director B.C.I.R.A.) asked for a little more information on the subject of the compound of iron and silicon to which Dr. Werner referred, and whether there was any likelihood of that material actually supplanting the high-silicon irons now so commonly used for chemical work and in other directions where great resistance to corrosion was required. He would also like to know whether the high-silicon irons—irons with about 15 per cent. silicon—were being made in Germany in the cupola or in some other type of furnace. As to pearlitic cast-iron, accounts he had seen gave comparisons between pearlitic cast-iron and other cast-irons, showing certain advantages that pearlitic cast-iron might have and which there was reason to suspect. He would like to know whether those people in Germany who had developed this material had compared the cast-iron with a pearlitic structure with irons from identically the same mixture but which had not received the mould-heating treatment required for producing the pearlitic structure. For some years it had been very difficult to discover what had been going on in Germany, and the lecturer had thrown a flood of light upon what had been for a long time a very obscure field of ironfoundry practice.

MR. LLOYD suspected that with the Schurmann cupola slag would be blown through the cupola and into the tuyeres on the far side, and that next morning they would find a considerable amount of slag and dust and possibly iron blown through the tuyeres into the bell on both sides as they reversed. He would like to know if there had been any trouble in that way. He also asked how they came over the difficulty of the provision of sight holes, and he took it they had to have a poke hole.

Applicability of Side-Blast Cupolas.

MR. ARTHUR MARKS thought British foundrymen were to be congratulated on having had an opportunity of hearing such an expert on the subject of German foundry practice as Dr. Werner. They were inclined to look upon the cupola purely from the engineering standpoint as merely a melting furnace, but it was not only a melting furnace but the means of manufacturing any grade or type of cast-iron that they desired. He was not convinced that it was possible in the Schurmann cupola to control the composition with the exactitude that it could be controlled in the ordinary cupola. Nor was he convinced that in small foundries they would not wipe out all the saving in establishment and upkeep costs. They must keep in mind the fact that any technical advance must show its commercial advantages. Otherwise it was not going to be an asset. As to carbon control, he thought many of the figures shown had not been properly correlated to the carbon content of the iron. He was not convinced that free oxygen had such a powerful influence as the figures shown would lead them to believe. The cupola which had been explained to them, apart from its practical disadvantages and commercial cost, particularly overhead and maintenance charges, did not, to his mind, enable one to control the composition of the iron with the same exactitude as was possible with the old cupola furnace.

Vote of Thanks.

Proposing a vote of thanks to Dr. Werner, DR. JOHNSON expressed a wish that similar lectures could be arranged in which representatives of other countries described their current practice.

MR. THOMAS TURNER, jun., in seconding the motion, said our mineral resources were greater than those of other countries, while our technique in some respects lagged behind. Germany was not so happily situated in respect of minerals, but they had brought their technique to a very high pitch.

The Author's Reply.

Replying upon the discussion, Dr. Werner referred to the comments on German coke, pointing out that in trying to find out the efficiency of the new furnace, they used not the best coke they could get, but coke which was below the average quality. With good coke the saving would be at least 20 per cent. Every figure he had given must be definitely correct, because the tests had been so numerous as to eliminate the possibility of error. As to the differences in temperature in Diesel work, to which he applied the word "enormous," he begged to be excused the use of the word. There was no blocking of the tuyeres in the Schurmann cupola. The upkeep of the cupola was no greater than that of a standard cupola.

Replying to Mr. Cook, Dr. Werner said that for testing the blast volume and pressure, a hydrometer, which allowed of adjustment according to barometric pressure, was used. Temperatures were always taken simultaneously. As to grain size, he could only refer Mr. Cook to the micrographs he had shown.

The method used for the determination of oxygen was described in Stahl and Eisen,* by Oberhoffer.

Replying to Mr. Pearce, the lecturer said that a special type of reverbatory furnace was used for the melting of high-silicon iron. The comparison between good iron and pearlitic cast-iron had been made and was available. For pearlitic cast-iron a special mixture is recommended. He assured Mr. Lloyd that the correct design of the tuyeres effectually prevents the blowing of the slag into the regenerator. Finally, he thanked his hearers for the reception they had given to his work.

Personal.

MR. H. MCQUARRIE has resigned the position of secretary and commercial manager to the Furness Shipbuilding Company, Limited, Haverton Hill-on-Tees.

MR. ARTHUR PUGH, general secretary of the Iron and Steel Trades Confederation, has been asked to serve on the Committee which is to be set up to inquire into the effect the London Pact is likely to have on the iron and steel, coal, textile, and dye industries.

MR. JAMES HORNE, chief hydraulic engineer of the Naval Construction Works of Vickers, Limited, has retired from active service. He has just completed 26 years' service with the firm, and will continue to act in an advisory and consultative capacity. He has been succeeded by Mr. E. C. Pearson, for several years Mr. Horne's principal assistant.

Wills.

MURRAY, LIEUTENANT-COLONEL H. S., chairman of Stanley Bros., Limited	£155,138
COLLINGS, A. S., of Tyndall Road, Redland, Bristol, constructional engineer	£6,635
WESTLEY, C. H., formerly in business at Dudley as a brassfounder	£54,642
RUSHWORTH, G., of Colne, head of Rushworth Bros., engineers and crane makers	£41,208
INGHAM, WM. P., of 2, Blenheim Terrace, Coatham, Redcar, Yorks, formerly of Middlesbrough, civil engineer, deputy chairman of the Leeds Fireclay Company, Limited, and a director of the Harrogate Red Brick Company, Limited (net personalty, £4,624)	£21,384

* Jan. 31, 1924 issue, Oberhoffer "Ueber Gas- und Sauerstoffbestimmungen," etc.

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IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—Business in the Cleveland iron market continues inactive, with but little indication of an early improvement in either home or export demand. Unfortunately, the foundries as a whole are badly off for work, and unless there is a change in the position, prospects for the rest of this year in the pig-iron industry must be far from bright. At this week's Tees-side market the tone was cheerless, and values were weak. No. 3 G.M.B. could be done at round about 82s. to 82s. 6d., with No. 1 87s. 6d., No. 4 foundry 81s. 6d., and No. 4 forge 80s. 6d. per ton.

In the hematite section also conditions are unimproved, the old and reputable firm of Messrs. Gjers, Mills & Company having closed down the two remaining furnaces at their Ayresome Ironworks. Thus the whole of the firm's plants are now idle, and the works are standing. At this week's market the reduction in output had no effect in stiffening prices, which, on the contrary, developed further weakness. Whereas a week ago East Coast mixed numbers were quoted at 92s. 6d., the price cannot now be put higher than 91s., and, in fact, one or two sales are reported to have been made at slightly under. The No. 1 quality is 6d. per ton more.

LANCASHIRE.—The local demand for foundry iron is reported by sellers to be better than it was, and some furnace agents for Midland makers say that they have recently booked quite a fair tonnage at prices ranging from 93s. to 94s. per ton delivered in Manchester. Some Lincolnshire No. 3 has also been sold here at a little less than Derbyshire, but no doubt this is because the first-named find a market for basic-iron.

THE MIDLANDS.—Orders recently placed in this area for foundry pig have been of limited extent, local ironfounders, with a few exceptions, being short of work, and consequently limiting their purchases to quantities sufficient to carry on from day to day. It is evident that some of the larger consumers have already placed their contracts to cover their requirements until the end of the year. Ruling prices for pig-iron are as follow:—Derbyshire No. 3 foundry, 85s. to 87s. 6d.; Staffordshire No. 3 foundry, 87s. 6d. to 90s.; Northants No. 3 foundry, 82s. 6d. to 85s.

SCOTLAND.—At Glasgow the pig-iron market continues very dull, with the price of Scotch No. 3 foundry still easy at 92s. 6d. per ton, f.o.t. furnaces. Continental foundry pig-iron is still on offer at 87s. 6d. to 88s. 6d., but the price is too close to home quotations to induce much buying.

Finished Iron.

There are reports of a slightly better demand for best iron, but the improvement is not sufficient to bring idle works into operation again. Some of the best-known South Staffordshire mills remain entirely inactive, and for the present there seems just as little prospect of their restarting in the early future. Whether anything will come out of the protests of the operative chain-makers remains to be seen, but they are complaining of the difficulty of working up the foreign material now being used in place of the reliable South Staffordshire iron which they have been accustomed to in the past. They have opened up a very important question which has much wider ramifications. One difficulty is that, although the future reliability of iron for many purposes is well recognised, the price at which it stands puts it out of competition with steel; and, unfortunately, manufacturers are unable to produce it any cheaper.

Steel.

At present there are few signs of revived activity in the steel industry, and at Sheffield suspension of deliveries, and in some cases cancellation of contracts are reported in consequence of the steel-workers' strike, while the market is hesitating and nervous. Demand for billets has slumped badly, and at the moment there is scarcely any business. In the heavy steel branches the outlook is very disappointing, but in the lighter sections matters are less depressing, though buyers are not purchasing anything more than will meet current needs. The market for ferro-manganese seems to have found its level at £13 10s. per ton delivered into steelworks, and the situation has now become much steadier. The tone of the tinplate market continues fairly steady; makers are, on the whole, pretty well booked, and are not pressing for forward business in face of the high cost of block tin, and the possibility of an advance in wages. Current quotations for the standard sizes are steady.—IC, 14 x 20, 112 sheets, 108 lbs., ruling at 23s. to 23s. 3d. per box net cash, f.o.b. Bristol Channel ports.

Scrap.

With few exceptions, markets for scrap metal correspond in conditions with those devoted to pig-iron, most of the foundries limiting dealings to actual immediate requirements. In Lancashire the selling prices for good foundry scrap are a little uncertain, 82s. 6d. per ton being occasionally reported as accepted, but as a rule dealers, unless very anxious to sell, ask 85s. per ton for ordinary broken machinery metal, and up to 87s. 6d. per ton for "textile." Demand for foundry material in Scotland continues disappointing in volume, with prices inclined to a weaker tendency. Machinery cast-iron scrap in pieces not exceeding 1 cwt., suitable for foundries, is now quoted 90s. to 92s. 6d. per ton, but the inquiry is still poor. Ordinary quality to same specification is 5s. per ton less, and for cast-iron scrap to steelworks specification about 83s. 6d. to 85s. per ton. Old cast-iron railway chairs are quiet, and lots are being offered at 87s. 6d. to 90s. per ton. Light cast-iron scrap is 72s. 6d. per ton to 75s. per ton, and, if mixed with fire bars, 2s. 6d. per ton less. The above prices are all per ton delivered f.o.t. consumers' works.

Metals.

Copper.—Movements in standard copper of late have disclosed few fluctuations of importance in current values, which continue, on the whole, quietly steady with a tendency to increased strength as autumn requirements influence consumptive demand. There has been a little more interest in evidence on the Continent, but German dealers are known to hold comparatively heavy stocks of the yellow metal, and these will naturally have to be absorbed by the consuming industries before new movements become prominent. Current quotations:—*Cash*: Thursday, £63 10s.; Friday, £63 10s.; Monday, £63 2s. 6d.; Tuesday, £63 2s. 6d.; Wednesday, £63.

Three months: Thursday, £64 10s.; Friday, £64 10s.; Monday, £64 2s. 6d.; Tuesday, £64 2s. 6d.; Wednesday, £64.

Tin.—Increasing strength is again the dominant feature of the market for standard tin, which maintains exceptionally firm in the values at the high levels recently established. Dealings are mostly three months, with recent sellers inclined to operate on the bull side. A great deal depends on how America takes the monthly visible supply statement and what response comes from U.S. consumers. Reports from the other side indicate that the American tinplate trade is very well engaged.

Stocks landing and afloat in Europe and America, according to Messrs. Ricard & Freiwald's statement, amounted to 20,390 tons, as against 19,462 tons for July, showing an increase in the total visible supply of 928 tons. Monthly supplies from all sources amounted to 8,710 tons, as against 8,167 tons for the previous month, deliveries in that period being 7,782 tons, as against 8,147 tons for July. The price of standard tin during the period was £254 per ton, as compared with £248 for the previous month.

Current quotations:—*Cash*: Thursday, £256; Friday, £257 15s.; Monday, £253 10s.; Tuesday, £252 10s.; Wednesday, £252 5s.

Three months: Thursday, £256 15s.; Friday, £258 10s.; Monday, £254 5s.; Tuesday, £253 10s.; Wednesday, £253 12s. 6d.

Spelter.—The market for this metal has maintained a steady tendency of late, fluctuations in values having been within very narrow compass. American reports have been distinctly better of late, and there have been more inquiries from consumers in Europe. Current quotations:—*Ordinary*: Thursday, £33 1s. 3d.; Friday, £33; Monday, £33 2s. 6d.; Tuesday, £33 1s. 3d.; Wednesday, £33.

Lead.—Transactions in soft foreign pig indicate a fair average demand, and with the increased activity stimulated by the resumption of work in the building trade, it is assumed that home requirements of the metal will, if anything, be heavier in the near future. Current quotations:—*Soft foreign (prompt)*: Thursday, £33 5s.; Friday, £33 5s.; Monday, £33 5s.; Tuesday, £33 1s. 3d.; Wednesday, £33 2s. 6d.